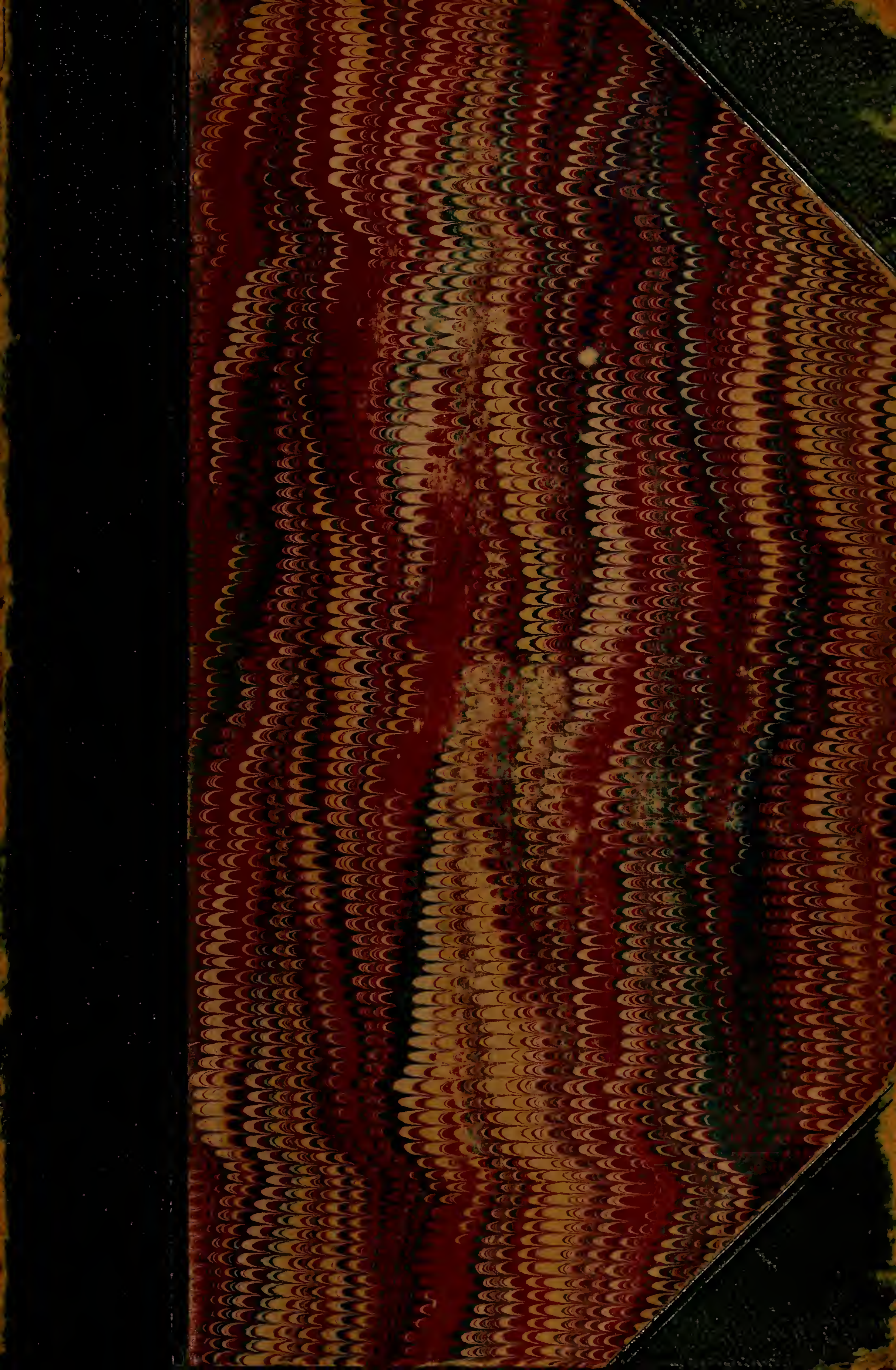

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THE DESIGNING AND CONSTRUCTION OF STORAGE RESERVOIRS.*

By ARTHUR JACOB, B. A.

Before entering upon such considerations as affect the selection of reservoir sites and their construction, a brief allusion to some of the most ancient works for impounding water may not be uninteresting. Of these the most prominent examples are undoubtedly to be found in Hindostan, where the magnitude and antiquity of the storage works cannot fail to arrest attention. These great works, surpassing in their immensity what are conventionally esteemed to be the wonders of the world, the production of other countries and nations, took their origin in the necessities of the people and the variableness of the climate of India, and were, in fact, great public works on which the welfare of the people mainly depended. The climate of India, although singularly uniform in some respects from year to year, is remarkably variable as regards the rainfall; and in order to guard against the disasters of famine and sickness, inevitably attendant on a scanty monsoon, the native princes were wont to make such provisions as large resources and an almost unlimited power enabled them, in order to obviate the difficulty that they had to contend with.

The rain records of India for several years past show that a scarcity of rain is indicated by periods of about five years, or that every fifth or sixth year is marked by a scanty rainfall over certain districts. The recurrence of these periods is, of course, not very clearly marked, but still it is sufficiently so to warrant, with approximate correctness, the prediction of scarcity and famine ; and such deplorable recurrence is, as all are aware, now reigning in India, and visiting with destruction, by sickness and hunger, some thousands whose sole dependence is upon a fair season of rain, and the successful maturing of their little crop of grain.

The natural expedient for guarding against the recurrence of these periodical calamities was evidently to be found in husbanding a scanty supply of rain-water for the purpose of irrigation, and this the people of India appear to have understood. They took advantage, in certain districts, of every nook and ravine, whether large or small, and converted them into storage reservoirs by throwing across banks of earth, or bunds, as they are termed, producing, in certain districts, such an elaborate and complete system of irrigation as can only be compared, for cost and completeness, to our railway system in England. Taking fourteen districts in the Madras Presidency, where tank irrigation was most generally relied upon, the records of the Indian Government show that there are no less than 43,000 irrigation reservoirs now in effective operation, and as many as 10,000 more that have fallen into disuse, making a total number of 53,000 storage works. The ave-

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*A Paper read before the Society of Engineers.

rage length of embankment is found to be about half a mile, the extreme limit of the series being a dam of the immense length of 30 miles. This ancient reservoir, called the Poniary tank, is no longer in use, the cost of maintaining such a length of bank in adequate repair having probably been found disproportionate to the advantage derived from the supply. The work, embracing an area of storage of between 60 and 80 sq. miles, remains however as a record of what the Hindoos are capable of. To quote a second example, there is the Veranum reservoir, now in actual operation as a source of supply, and yielding a net revenue of no less than £11,450 per annum. The area of the tank is 35 sq. miles, and the storage is effected by a dam of 12 miles in length. In order to bring the immensity of this system of storage works within the reach of statistical minds, it has been calculated that the embankments contain as much earth as would serve to encircle the globe with a belt of 6 ft. in thickness. To show that these are not singular examples, one other embankment of remarkable size may be alluded to. This embankment, of somewhat singular construction, was built on the island of Ceylon, and bears testimony that the Singalese monarchs were not behind their neighbors in public spirit or enterprise. The embankment was composed of huge blocks of stone strongly cemented together, and covered over with turf, a solid barrier of 15 miles in length, 100 ft. wide at base, sloping to a top width of 40 ft., and extending across the lower end of a spacious valley.

Thus it will appear that the practice of embanking across valleys, for the purpose of retaining the surface water, has for ages been in operation. There is no doubt that the disposal of some of the most remarkable works in India is not what it might, with advantage, have been ; the fact remains, however, that the desired end was attained, and if the earthworks were disproportionately extensive, it was a source of satisfaction at least for the projectors to know that they cost, as a general rule, little or nothing, the practice in those days being to press whatever labor was required, rendering in return nominal wages or none at all.

The two main questions that it is proposed to submit for consideration are, first, the selection of a reservoir site ; and, secondly, the leading principles to be observed in the designing and construction of storage works.

The purpose or purposes for which the work may be required will, of course, affect materially the choice of a position, as well as the details of the structure itself; but certain general principles are available for our guidance in every case, after considering which, it is proposed to dwell upon such points as apply to the special purposes for which reservoirs may be constructed.

The first and most essential point for accurate determination by the engineer is undoubtedly the amount of rainfall, both maximum and minimum, that may be expected in the district under examination ; and, having arrived at reliable data on this point, the next consideration will obviously be, what amount may be made available, due allowance having been made for evaporation and absorption. When we know that the annual depth of rainfall taken all over the world varies, according to the locality, between zero and 338 in. or 28 ft. deep (which excessive amount was on one occasion registered in the hill district of Western India), it will be obvious how little ground there will be for assumption, in the examination of any district hitherto unexplored, with regard to the question of its rainfall. In the examination of any given country, however, there are certain phenomena connected with the rainfall that will be found of almost invariable acceptation, and may with advantage be borne in mind.

The rainfall will, as a general rule, be greatest in those districts that are situated towards the point from which the prevailing winds blow. If Great Britain for instance be taken, the western districts will be found the most rainy. The very reverse, however, of this phenomenon is noticed in the neighborhood of mountain ranges. If the wind prevails from one side rather than from the other, it is found that the greatest rainfall is on the leeward side of the range, and the probable solution of the matter is, that the air, highly charged with moisture, is carried up the hills by the wind until it comes into a cold region of the atmosphere. Condensation of the watery vapor immediately takes place, and the result is a fall of rain on the side of the mountain range remote from the prevailing wind.

To this cause may also be attributed the fact that the rainfall is always greatest in mountainous districts, while it by no means follows that elevated plains are more abundantly supplied with rain than land lying nearer to the sea level. The principles are remarkably exemplified in the southern part of the Bombay Presidency, where the author has had occasion to study the subject of rainfall. The Western Ghauts run parallel to the coast, rising to a height of 4,500 ft. above the sea, and form the western support of the great table-land of the Deccan, the mean elevation of which may be taken at 3,000 ft. In the rainy season the south-west monsoon, blowing from the sea, impinges against the ghauts, and while passing onwards to the Deccan, parts with its moisture to the average annual amount of 254 in. On a spur of mountain that runs eastward, the pluviometers are found to register but 50 in.; and about 40 miles farther inland the rainfall is not more in some places than 15 in., which is considerably less than that registered in the lower-lying districts of the Presidency.

In civilized countries like our own much valuable information is as usually available regarding the rainfall, if not applying actually to the district under examination, then probably to some neighboring districts, enjoying the same physical characteristics; but when any project of great importance is in contemplation, it will not be sufficient to take the returns of adjoining districts as accurate information of the rainfall at the exact locality fixed upon for the construction of the works. It will be necessary to establish rain-gauges at different points over the catchment basin of the valley from which it is intended to obtain the supply; and daily observations of these gauges must be taken for comparison with a series of simultaneous observations taken and recorded at the nearest station at which the rainfall has been regularly and carefully noted. It is evident that a comparison of the several observations taken over the area of water-shed with those registered at the permanent station, will convey a just estimate of the amount of maximum and minimum rainfall that may be relied upon.

The amount of rain falling upon the ground is not, however, the point to be determined, though it will aid considerably as a guide to the engineer. A considerable quantity of all the rainfall is either absorbed by the ground or evaporated before it reaches the point at which it can be made available for storage. Regarding, then, first the question of absorption, it must be apparent that no two districts, unless they are exactly identical in soil, inclination of surface, and under similar circumstances of cultivation, can give on examination the same comparative result of rainfall and evaporation. If one district or unit of area be similar to the other in all respects but the surface inclination, that which has the greatest slope will, as a rule, give the largest percentage of water available for storage, because of course there will be less time for the rain to be absorbed. Again, the degree of cultivation will materially affect the result when two areas, otherwise precisely similar in their physical conformation, come to be compared one with the other, it being evident that an open and well-drained soil will be more favorable to the retention of water falling upon it than compact and impervious land. In every case the physical features of a district will each and every one of them force itself on the attention, as influencing the conclusion to be arrived at. If any general rule can be applied, it may be said that the greater the slope of the valley, the more rapidly it will throw surface water off; the more denuded the surface is of soil of any kind, the less will the escape of rain-water be retarded; and the more compact the rocks composing the geological structure of a district, the better will the circumstances be for impounding water. The volcanic rocks and those of the granite order will be as favorable as any that could be desired; while, on the other hand, porous rocks, such as the sandstones, chalk, etc., are too absorbent to offer the desired conditions for storage. It is not here asserted that all the water absorbed by porous rocks is necessarily intercepted from passing away to contribute to storage supply; much of it may be lost by evaporation and absorption by vegetables, but a considerable portion will often be found to contribute in the form of springs, if the disposition of the strata be favorable.

As a further source of loss, evaporation from the ground as well as from the surface of the reservoir, must be taken into consideration. The circumstances attending the latter source of loss will be considered further on, as this does not affect the question of how much of the total rainfall may be made available.

The question how much water will be evaporated at any moment from the surface of land is one involved in considerable difficulty; and so many disturbing elements enter into the solution of the problem, that its accurate determination may be regarded as hardly possible of attainment. The hygrometric state of the ground's surface, the aspect of the sky, the amount of wind, and the temperature, will all, in their degree, exercise a sensible influence on the amount of water that the ground will give off from its surface; so that, in fact, it is doubtful whether any reliable and philosophically correct conclusions can be arrived at. The resultant facts from such experiments as have been carefully conducted afford, after all, the only data for the engineer to arrive at any general conclusion by; and for forming a rough estimate for the probable available rainfall of a district, the following proportions of available actual rainfall may be accepted as furnishing general data; but they are not meant to obviate the necessity of a careful and specific examination of the circumstances likely to affect the design of any particular work :

Steep surfaces of granite, gneiss, and slate	100
Moorland and hill pasture..................	60 to 80
Flat cultivated country....................	40 to 50
Chalk......................................	0 to 0

In order to arrive at more specific, and truly reliable results, the engineer will have to make a series of accurate observations on the discharge of the stream or streams that carry away the rainfall of a district; and by doing so, and at the same time comparing the result with the amount of rain registered by the gauges—which should also, of course, be kept with accuracy in the locality under examination—an approximately true estimate of the available rainfall will be arrived at.

If there is time in the preparation of a project to make the necessary examination of a district, it is evident that the results will speak for themselves; and there will be no necessity to enter into abstract speculations concerning the theory of the influences affecting loss by either evaporation or absorption.

In proportioning the size of a storage reservoir to the area of the catchment basin, the engineer will, of course, in the first instance be guided by the requirements of the work. The object of the undertaking may be any one of the following :

To husband a scanty rainfall.

To check the injurious effect upon the country by floods.

To add to the discharge of a stream, by preventing the escape of the flood waters.

The amount of storage will always be part of an engineer's data in designing works. It will either be his object to store the whole of the water that the drainage area will afford, which will be the case in impounding water for irrigation, for example; or a certain fixed demand, governed by the want of a town or other requirements, will determine the amount of the rainfall that it will be necessary to retain for supply. In England the demand for water supply may be reckoned at from 150 to 180 days, depending on the amount and the constancy of the rainfall; as a rule, the six months' supply will be the safest to adopt. The following Table, extracted from Mr. Beardmore's work, shows the proportions that have been observed in designing some of the best constructed reservoirs. (See Table A, page 5.)

From this it appears that the proportion between the amount stored and the total rainfall varies between one-half and one-fourth.

The rule suggested by Professor Rankine " for estimating the available capacity required in a store reservoir, that founded upon taking into account the supply as well as the demand," is probably the best that can be adopted in designing waterworks for the supply of a town; "for example, 180 days of the excess of the daily demand above the least daily supply, as ascertained by gauging and computation in the manner above described." In order that a reservoir of the capacity "prescribed by the preceding rule may be efficient, it is essential that the least available annual rainfall of the gathering grounds should be sufficient to supply a year's demand for water." In calculating the capacity of a storage reservoir, the consideration of the surface evaporation must not be disregarded, especially when the works are designed for tropical or very dry climates. The amount of loss will in some cases be very considerable, for whatever depth of water be assumed to pass away into the air, it must be regarded as extending over the whole surface of the reservoir; or, in fact, the cubic quantity will be equal to the product of the depth evaporated away and the mean surface area of the reservoir as the water rises or falls throughout the year. Some have gone the length of asserting that the amount of evaporation from the surface of large and

TABLE A.

LOCALITY.	Height above Sea.	Drainage Area.	Total Discharge for the Year.	Discharge per Square Mile.	Representing Rainfall per Annum.	Registered Rainfall per Annum.	Reservoir Room per Square Mile.	Proportion of Storage to available Rainfall.
	ft. ft.	sq. m.	c. ft. per m.	c. ft. per m.	in.	in.	c. ft. in. mill	
Bann Reservoirs, 1837-38	400 to 2800	5.15	1092.6	210 2	48 0	72.0	56 0	½
Greenock, 1827-28, flat moor	512 to 1000	7 88	1416.6	197.7	41.0	60.0	38.0	2-5
Bute, 1826	200 to 350	7 80	819.0	105.0	23.9	45.4	....	......
Glencorse, Pentland Hills	734 to 1600	6.00	600 0	100.0	22.3	37 0	7 66	3-10
Belmont, 1843, moorland.	850 to 1600	2.81	630.4	224.3	50 7	63 4	26.8	¼
" 1844, "	....	....	412.8	146.4	33 3	50 0	....	......
" 1845, "	....	....	511.2	181 9	41 2	55 0	....	.....
" 1846, "	....	....	411.3	146.3	33.2	49 8	....	......
Rivington Pike, 1847	800 to 1545	16.25	2880 0	176.7	40.0	55.5	29 6	⅓
Longendale "	500 to 1800	....	....	....	49.5	55 5	.. ..	......
Swineshaw "	500 to 1800	.... .	....	....	37 0	49 3	....	......
Turton and Entwistle, 1836	500 to 1300	3.18	576.7	181.3	41.0	46 2	31.43	⅓
" " 1837	....	.. .	548.2	172.3	39 0	48.2	....	......
Bolton Waterworks	800 to 1600	.80	100 2	125.2	32.7	....	25.6	1-3
Ashton " 1844	800	.59	40.7	65.5	15.5	40.0	21.0	4-7

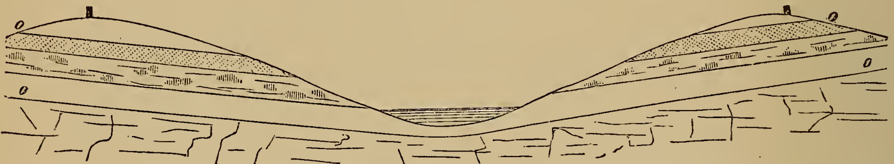
deep bodies of water is probably nothing at all, or, at any rate, not worthy of consideration; whilst others assume a much larger amount of loss than appears to be supported by observation. The following extract from the article "Physical Geography," published by the Society for Promoting Useful Knowledge, expresses intelligibly the conditions that tend to promote evaporation:

"Other things being equal, evaporation is the more abundant the greater the warmth of the air above that of the evaporating body, and least of all when their temperature is the same. Neither does much take place whenever the atmosphere is more than 15 deg. colder than the surface upon which it acts. Winds powerfully promote evaporation, because they bring the air into continual as well as into closer and more violent contact with the surface acted upon, and also, in the case of liquids, increase by the agitation which they occasion, the number of points of contact between the atmosphere and the liquid.

"In the temperate zone, with a mean temperature of 52¼ deg., the annual evaporation has been found to be between 36 in. and 37 in. At Cumana, on the coast of South America (N. lat. 10), with a mean temperature of 81.86 deg., it was ascertained to be more than 100 in. in the course of the year; at Guadaloupe, in the West Indies, it has been observed to amount to 97 in. The degree of evaporation very much depends upon the difference between the quantity of vapor which the surrounding air is able to contain when saturated and the quantity which it actually contains. M. Humboldt found that in the torrid zone the quantity of vapor contained in the air is much nearer to the point of saturation than in the temperate zone. The evaporation within the tropics, and in hot weather in temperate zones, is on this account less than might have been supposed from the increase of temperature."

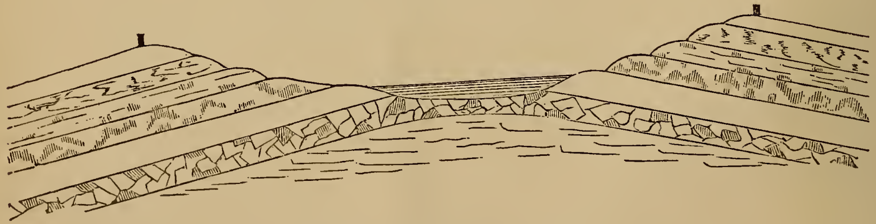
Thus it appears that evaporation, under highly favorable conditions, may take place to the extent of 9 ft. in depth—an allowance that will demand careful consideration in designing storage works. In India, where from the extreme dryness of the atmosphere the evaporation is found to be considerable, the usual allowance made by engineers for the evaporation from the surface of storage reservoirs is at the rate of ½ in. of depth per diem for eight months in the year. Regarding the results that have been arrived at in Bombay, this allowance would appear to be about double what is necessary, for the observations extending over five years give a mean daily evaporation of less than $\frac{1}{4}$ in. In Bombay, however, the atmosphere is much more humid than that experienced on the great table-land of the Deccan ; and in Madras, where reservoirs are the specialty, it is probable that the actual loss is not far from being a mean between the two fractions. In Great Britain the mean daily evaporation is found to average less than the the tenth of an inch.

Fig. 1.



SECTION ACROSS SYNCLINAL AXIS.

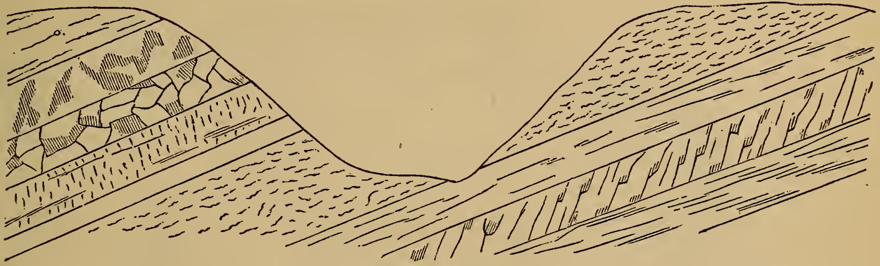
Fig. 2.



SECTION ACROSS ANTICLINAL AXIS.

In estimating the quantity of storage water that will result from the drainage of any particular district, it will be essential to consider carefully the geological disposition of the strata characterizing the locality in which it is contemplated to establish the works. This, although a matter that may influence the effectiveness of an undertaking to the extent of success or failure, will appear to the purely practical man to imply a degree of refinement that is uncalled for. There will be no difficulty, however, in showing that the geological conformation of a district may be such as, on the one hand, to materially contribute to the efficiency of a storage reservoir, or on the other to prove so defective that no engineering skill or pecuniary outlay could remedy it. A condition of geological structure perhaps the most favorable that could be imagined is that shown in Fig. 1. This diagram represents a geological section taken at right angles, or nearly so, to the axis of the valley that it is proposed to convert to the purpose of storage. This somewhat peculiar structure is what is geologically termed synclinal, the beds inclining away from the axis of the valley, and is the result of an upheaving force having taken place underneath the points of greatest elevation. Subsequent to the upheaval and consequent displacement of the strata, the process of denudation has taken place, cutting the upper beds, and leaving the outcrop exposed, not only inside the basin, but in the adjoining valleys at O and O. Now, it is evident that if the highest ridges bounding the valley be taken to mark the line of watershed, and therefore limiting the area of the catchment basin, it is possible that the estimate of the amount of supply may be found far short of what the district will yield. A certain proportion of the rain falling upon the outcrop at the points O O will be absorbed by such of the strata as are porous, and the water, percolating through the bedding, till an impervious stratum is met with, will find its way down the course of the stratification, till it ultimately reaches the reservoir in the form of springs, and contributes more or less to the maintenance of the supply. The converse of this condition of things will be readily understood by reference to Fig. 2. It also represents a section taken directly across the valley of the proposed reservoir. Here the strata of the earth's crust incline against each other consequent upon some disturbing force having taken place to elevate them, and are said to be anticlinal to the axis of the valley. In order to account for the formation of a valley on the summit of the ridge, that at first was thrown up, it is to be understood that the upper beds suffered fracture in the process of upheaval, and subsequently were exposed to denudation. These valleys of elevation are evidently not to be desired as situations for the establishment of storage reservoirs. The area of the gathering grounds will be much more limited than the extent of the watershed would appear to indicate; and cannot safely be relied upon to give an estimate of the quantity of water that the valley will afford. A certain amount of water will undoubtedly pass over the surface in times of heavy and continued rain, before it can be absorbed; but there is no doubt that of all the water absorbed by the ground, by far the greater portion will follow the inclination of the strata, and come out as springs in the adjoining valleys.

FIG. 3.



VALLEY OF DENUDATION.

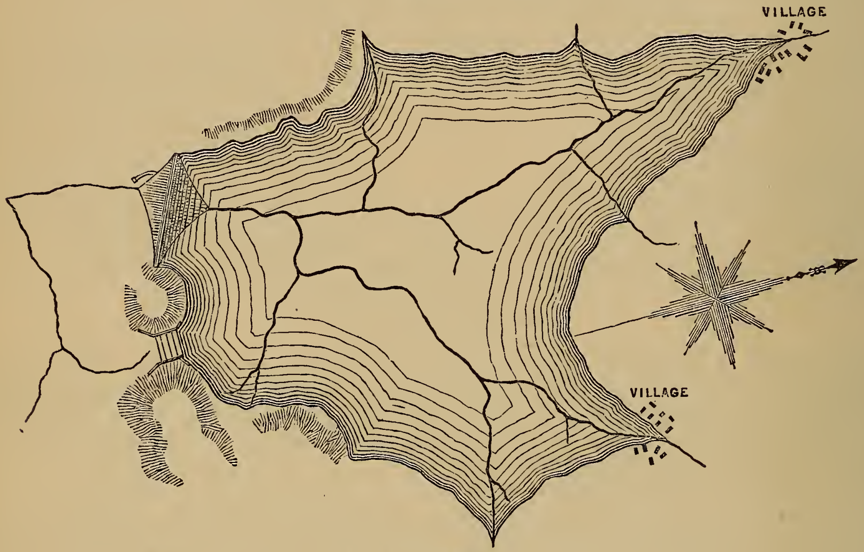
Fig. 3 shows a geological section that combines in it favorable and unfavorable conditions for the storage of water. On one side the outcrops of the strata are found to extend beyond the highest point of watershed line, whilst on the other side the strata incline away, producing such a condition as would favor the escape from the valley of the water absorbed.

Certain rules are in general use for estimating the quantity of the total rainfall that will be lost by absorption and evaporation, with a view to determining the proper proportion to be observed between the reservoir and the area of the catchment basin. Two-thirds of the whole fall is sometimes taken to represent the loss that may be expected from the drainage of any district, in general terms, one-third being assumed as the amount that may actually be intercepted for utilization. Some authors leave a much smaller margin, and state that fully two thirds of the total rainfall may fairly be taken as available for storage. This is a large discrepancy when the application of the rules is taken to be general; but when the statements are applied to separate districts and different countries, there is nothing irreconcilable in them. General rules are undoubtedly of much value if they be received with qualification, and are not adopted as of absolutely universal application. They cannot, however, with safety be substituted for specific investigations, when so much depends on starting with accurate data.

RESERVOIR SITES.

The special requirements of each particular case will, as a general rule, go far towards determining the selection of a site for the establishment of storage works. Assuming, however, that there is a considerable extent of country situated advantageously in relative position to the locality at which it is proposed to utilize the water, and that there is a choice of ground, the point to be considered chiefly will be the natural lie of the country. To throw an embankment across a valley at any point without due regard to the configuration of the ground would most probably result in an expensive and ill-designed scheme; for under such circumstances the cost of the dam would bear a very large proportion to the quantity of water stored. It will rarely happen that, in the examination of the resources of any particular piece of country, some special features will not present themselves, favorable to the situation of storage works. The most advantageous disposition of the ground will be when two spurs of high land approach each other, forming a narrow outlet for the stream, and leaving a wide space above above them in the valley for storage. Such a configuration is not uncommonly met with at the junction of two streams, as shown in Fig 4. This is merely a sketch from memory, by the author, of a reservoir that he designed in India for purposes of irrigation; and it will be evident that the disposition of the ground was singularly favorable in every respect for the construction of a large storage work. The area of the reservoir, as designed, was about three square miles, and the maximum depth 90 ft., the area of the catchment basin being about 60 square miles. Such favorable situations for storage are of somewhat rare occurrence; for when the contour of the land is what is desirable, it may be that the area of water-shed is not adequate, or possibly the geological condition of the ground may be unfavorable, or the materials for the construction of a sound bank are not available. In examining large tracts of country in India, with a view to the establishment of irrigation reservoirs, the author found that more reliance was to be placed on a careful examination of the map in the first instance, than on the common plan of making personal explorations of the country. A good map will show at a glance, especially if the hill-shading has been carefully engraved, the points at which the supply will be found sufficient to justify the undertaking; and will probably furnish a pretty true indication of sites at which embankments may be advantageously constructed.

Fig. 4.



IRRIGATION RESERVOIR.

In tropical climates, where the rainfall is in places very scanty, and where the land is not of great value, it not unfrequently happens that such situations prove available for the establishment of large storage works as would not under any circumstances be made available in England. These sites are to be found, not at the head of a valley, but at some considerable distance down the course of a stream, where, the general inclination of the country being slight, a low embankment serves to store a very large area of water. The apparent disadvantages of such a site for storage are the large area of land swamped and lost to the cultivator and to Government, and the great surface exposed to evaporation under a tropical sun and the influence of a dry wind. In India, the first objection is one of comparatively little moment, considering that in those districts where irrigation is most required the value of land is very trifling. From 1s. to 2s. is about an average rent per acre, where land is under dry crops; but when water is available, the cultivators can, with profit, afford to pay 30s. per acre. It is therefore evident that, so far as Government is concerned, there is no sacrifice in the matter, but, on the contrary, an unspeakable benefit is conferred on those landowners who hold farms below the reservoir ; and an ample supply of water is stored in the dryest seasons to mature those crops whose failure almost inevitably reduces the people to the verge of starvation. The evaporation from these lakes is, beyond question, a source of very considerable loss, and one that admits of no possible abatement. Estimated as above, at about half an inch vertical for eight months of the year, the loss frequently amounts to one-third of the whole body of water stored. As a set-off against this and other objections, the facilities for constructing these reservoirs of great extent, are considerable. In the first place, the embankments, being very low, are rapidly and cheaply constructed by native workmen; and when finished, the head of water even at the deepest point is not sufficient to try the work to any great extent. Further, the greater the extent of the reservoir, the less inconvenience is experienced from silting. The streams, owing to the suddenness of the rainfall, come down heavily charged with earth in suspension, the mass of which is deposited like a miniature delta at the influx of the reservoir, instead of passing on and resting near the embankment, as invariably occurs in reservoirs of small extent. The immense consumption of water necessary to confer any appreciable benefit by irrigation is of itself the strongest argument in favor of these broad and shallow reservoirs ; for it is not possible to find in the upper part of a valley such sites as would store the requisite quantity of water without an embankment of excessive dimensions ; and moreover, the catchment area in such situations is not usually sufficient to serve, with a scanty rainfall, for the supply of a very large reservoir. It is not, of course, maintained that this mode of storing water is by any means applicable in England, for the circumstances and requirements in each case are wholly dissimilar.

SUPPLY.

The reservoir site being supposed everything that could be desired, as regards the disposition of the ground, the supply will next engage attention as a matter of course. Assuming that the gathering grounds are sufficiently extensive, it is presumed that the reservoir will be constructed to contain sufficient water to meet the maximum demand, whatever that may be calculated at; and in order to determine with accuracy what capacity the reservoir will have with different heights of embankment, it will be necessary to carry out certain levelling operations over the ground. The least elaborate manner of proceeding will be to run a series of cross-levels through the valley, referring all to the same datum, and by comparing these levels to ascertain what the average depth will be for a given height of bank. Having decided the height of the water-level, the next operation will be to contour round the basin, and to survey the boundary-line. In this way may be acquired sufficient knowledge as to the storage capacity, to justify the procedure with the work. When the execution of the project has been determined upon, it will be advisable to make a more accurate survey of the bed of the valley, and this can best be done by covering the whole plan with a series of contour lines at a vertical distance from each other of about 5 ft. This kind of survey will be of lasting value to the engineer, for it will enable him to calculate what quantity of water the reservoir will contain at each foot of depth ; and, consequently, he will know, from a mere inspection of the gauge in the reservoir, how much water he has at his disposal for service.

It has been assumed that the gathering grounds are sufficient to maintain the requisite supply in the reservoir ; but it may be well to pause and inquire what extent of water-shed will be sufficient to furnish a given supply, and what method may be adopted for supplementing an insufficient drainage area. It has before been remarked that the only reliable information, when there is any question as to the sufficiency of the rainfall or the area of the catchment basin, can be derived from careful gaugings of the stream or streams that may be depended upon to contribute to the supply. If the catchment area is very large as compared to the capacity of the reservoir, a mere inspection of the map and an exploration of the ground will generally be conclusive as to the sufficiency of the supply for storage. Should there not be such conclusive evidence on this point, it must be determined by measuring the quantity of water that absolutely flows off the ground, at the same time gauging the rainfall. This latter precaution would appear unnecessary, but in truth it is of great value, for it will furnish, by comparison with the rainfall registers that have been kept through the same year, and a series of previous years, evidence as to the amount of available rainfall that may be expected during terms of comparative drought. If the supply of a town with water be the desideratum, the rule to be rigidly observed is that of making a minimum supply meet the maximum demand, and therefore it is of the highest importance to determine beyond any doubt, what the minimum yield of a catchment basin will be.

As a mode of supplementing an insufficiently large drainage area, catchment drains or feeders have frequently rendered good service. These are cuts that are carried outside the water-shed line to arrest the surface drainage and catch the contributions of small streams, and conduct the water into the reservoir. The greater the area enclosed between catchment drains and the water-shed line, the more valuable will they be as aids to the supply of the reservoir. They of course virtually extend the area of the catchment, adding so many square miles or acres to the rainfall.

DESIGNING OF WORKS.

Knowing the exact requirement of a given population, or rather having fixed, after every consideration, the daily consumption of every individual that it is proposed to supply, there will be no difficulty whatever in proportioning the reservoir to the demand upon it. It is sometimes necessary, however, to provide reservoirs for the purpose of preventing damage to the country by floods, and in this way the inconvenience and injury naturally consequent upon very sudden and excessive falls of rain may be to a great extent obviated. The duty of the reservoir will be to arrest all water in excess of what the stream can carry within its banks, and to dispose of this excess water, so to speak, in detail, after the excessive rainfall has become moderated. A comparison of a stream's discharge, taken at highest floods, with the quantity that it can carry without overflowing its banks will show the excess that has to be retained by the reservoir ; and these data can only be arrived at through a carefully kept record of the extent of the floods and of their duration. The maximum flood in this consideration will not be that which rises to the greatest height for a short time, but will be the product of the excess above what the river can discharge by the length of time the flood lasts; which will, in fact, be the necessary capacity of the reservoir.

The Table given on a preceding page will afford an interesting study when compared with the following Table, extracted in part from the same work. The first gives a comparative view of the volume of water gauged and stored in small hill districts, the last column indicating the proportion of the total available rainfall to the amount actually intercepted for storage. The following Table shows the ordinary summer discharge of various rivers, streams, and springs, as unaffected by immediate rain. (See Table B, page 11.)

Where the reservoir is designed to check the injurious effects of floods, the proportion of the storage to the rainfall will, in most cases, be much smaller than what would be necessary to provide for the better part of a whole year's fall of rain. for it is not probable that the maximum known flood can ever exceed the amount that it would be necessary to store for economic purposes.

PROPORTIONS OF BANK.

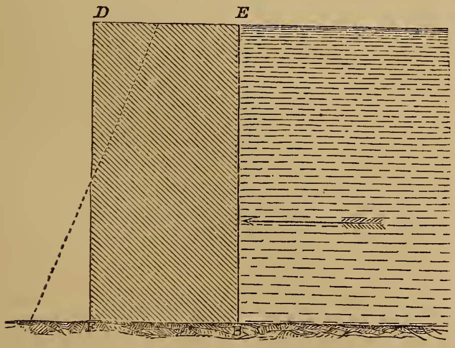
The proper proportion to be given to an embankment for the support of water is a question that appears to admit of a good deal of difference of opinion, some designers taking one view, some another, of the proper theory that is to determine the dimensions of a bank. Some few, with whom the author cannot agree on this point, maintain that a bank ought to be designed with strict reference to its theoretical power of resisting hydrostatic pressure, or the effort of the water to displace it. Regarding the question in its abstract form, it will be evident that any structure intended to sustain the pressure of water may be supposed to fail in one of two ways—either, in the first place, by yielding to the horizontal pressure of the water and overturning, or by progressive motion, *i. e.* sliding on its base. In considering the first theory, that of resistance to overturning, the easiest method of examining the question will be to take a simple example of a vertical rectangular wall, and ascertain what power it exercises to resist the pressure of water. The pressure of water upon any plane surface immersed is known to be equal to the area of that surface, multiplied by the depth of its centre of gravity below the level of the water and by the weight of a unit of water. Generally speaking, the

TABLE B.

RIVERS.	Height above Sea.	Drainage Area.	Total Discharge.	Discharge per Sq. Mile.	Representing Rainfall per Annum.	Total average Rainfall per Annum.
	Valley Hill. ft. ft.	sq. miles.	c. ft. per min.	c. ft. per min.	in.	in.
Thames at Staines, chalk, greensand, Oxford clay, oolites, etc.	40 to 700	3086	40,000	12.98	2.93	24.5
Severn at Stonebench, silurian	400 to 2600	3900	33.111	8.49	1.98	.....
Loddon (February, 1850), greensand	110 to 700	221.8	3,000	13.53	3.01	25.4
Nene, at Peterborough, oolites, Oxford clay, and lias	10 to 600	620.0	5,000	8.45	1.88	23 1
Mimram, at Panshanger, chalk	200 to 500	50.0	1,200	2.4	5.5	26.6
Lee, at Lee Bridge, chalk (Rennie, April, 1796)	30 to 600	570 0	8,880	15.58	3 53	.....
Wandle, below Carshalton, chalk	70 to 350	41.0	1,800	43.9	9.93	24.0
Medway, dryest seasons (Rennie, 1787), clay	.....	481.5	2,209	4 59	1 04	.....
Ditto, ordinary summer run (Rennie, 1787)	.....	481 5	2,520	5 23	2.19	.....
Verulam, at Bushey Hall, chalk	150 to 500	120.8	1,800	14.9	3 37	.....
Gade, at Hunton Bridge, chalk	150 to 500	69 5	2,500	36.2	8 19	.....
Plym, at Sheepstor, granite	800 to 1500	7.6	500	71.4	15.10	45 0
Woodhead Tunnel, millstone, grit	1000	.....	139	.....	.....	46 0
Glencorse Burn	750 to 1600	6.0	130	21 6	4.9	37.4

unit adopted in calculations is a foot; and the unit of water being taken at a cubic foot, weighing 62.5 lbs., the resulting product from the multiplication of the three quantities will give the pressure in pounds on the surface immersed. Let it be supposed, for simplicity, that water to the depth of 10 ft. has to be sustained by a vertical rectangular wall, as in Fig. 5. It is usual to take but 1 ft. length of the wall for the calculation, though it will not affect the result whether 1 ft. or 100 ft. be the length assumed. We then have the surface under pressure = 10 sq. ft., the depth of the centre of gravity = 5 ft., and the weight of a cubic foot = 62.5 lbs., the product of which quantities gives us 3,125 lbs. pressure on 1 ft. length of the wall. But this pressure is not the whole of the force that the wall has to resist; the leverage that it exerts must also be taken into account. In the example under consideration—viz. that of a vertical plane with one of its sides coinciding with the surface of the water, as in Fig. 5—the whole of the pressure is so distributed as to be equal to a single force acting at a point one-third of the depth from the bottom. Thus, the total force to be resisted by the wall is 3125 × 3.33 = 10,406, which is the moment tending to overturn the wall.

FIG. 5.



It is evident that a certain weight of the wall must be opposed to this overturning force; and as the height of the wall and the length are determined quantities, the thickness alone remains for adjustment. But as a rectangular wall in upsetting is considered to turn upon a single point, F, in the Figure—viz. the outer line of the wall—there will be a certain amount of leverage to assist the wall in resisting the pressure of the water. This leverage is the horizontal distance of the centre of gravity of the wall from the turning point, F, and when the structure is rectangular and vertical, it is equal to half the thickness. The amount of the wall's resistance will then be equal to the number of cubic feet in one foot of its length multiplied by the weight of a single cube foot of masonry and by half the thickness of the wall. Taking $w =$ weight of a cubic foot of water $= 62.5$ lbs., $w^1 =$ weight of a cubic foot of brickwork, say 112 lbs., $x =$ thickness of the wall, and $h =$ the height, the conditions of simple stability will be fulfilled when

$$w^1 \times h \times x \times \frac{x}{2} = w \times h \times \frac{h}{2} \times \frac{h}{3} \quad \ldots\ldots\ldots \quad (1)$$

$$\frac{w^1 h x^2}{2} = \frac{w h^3}{6};$$

and solving for x, we get

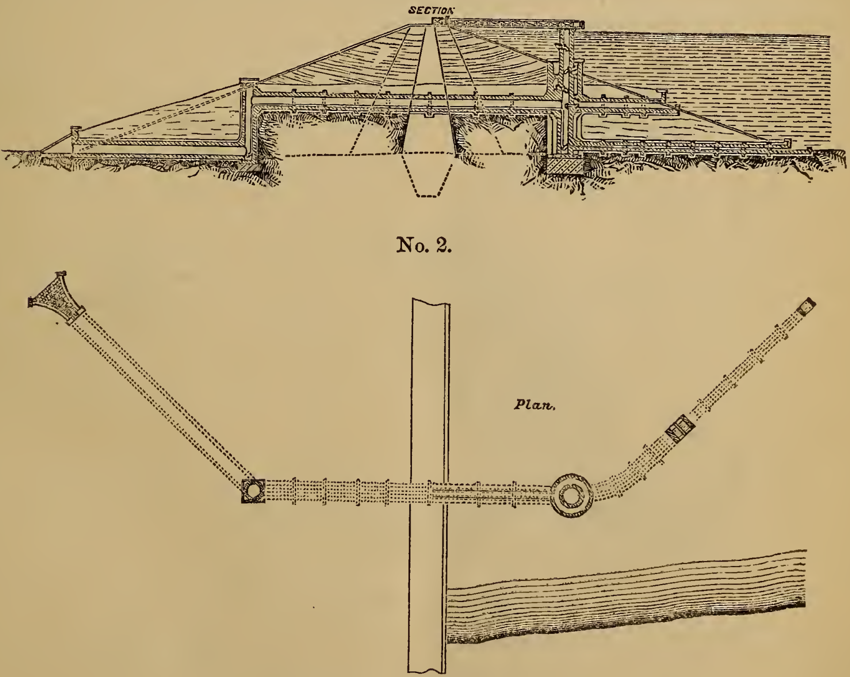
$$x = \sqrt{\frac{w h^2}{3 w^1}} \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

the thickness of the wall = 4 ft. 4 in.

A simple example has been selected for illustration; but of course a rectangular section of wall would not be found generally applicable in practice, nor would it be convenient to limit the dimensions of a retaining wall of whatever kind to the minimum that would sustain the pressure. If this principle of calculation be applied to ascertain the stability of a bank of earth with long slopes of $2\frac{1}{2}$ or 3 to 1, it can easily be shown that in every case the resistance of the bank to overturning is greatly in excess of the horizontal leverage exercised by the water sustained.

The only theory, then, in any degree tenable, is that assuming a bank in yielding to the pressure of water to slide on its base. In order to conceive how this can apply, it is necessary to assume the embankment to be a rigid body resting, for a given length of its section, on a horizontal plane; and without any adhesion, or a very small fraction, existing between the surfaces pressed. The amount of the friction, however, is just the point upon which the whole matter hinges, and until it has been ascertained that the surfaces of earth that are carefully incorporated with one another have any such thing as a co-efficient of friction, it is idle to to pursue the investigation by a mathematical mode of reasoning. The conditions of stability will be satisfied when the horizontal component of the water's pressure against the bank will equal the weight of the bank, plus the vertical pressure exercised by the water to hold it down and multiplied by the co-efficient of friction; but nothing is known of this co-efficient, and consequently the equation remains incapable of solution. As a matter of fact, embankments do not slide bodily forward on their base when they fail, but give way from other causes than mathematical reasoning can supply. Landslips, it is true, to some extent support the principle that maintains the sliding of embankments; but, here, the circumstances are widely different. Landslips either take place when a mass of earth rests upon an inclined surface of rock, with an ample supply of water to lubricate the surfaces in contact, or else they are the result of cutting or embanking earth to a higher slope than the material will stand at; the infiltration of water also in this case is the chief agent in producing the effect, acting as a lubricant, and causing the earth to assume its natural slope. In each case the surface of separation is an inclined plane, an element that does not enter into the question of the stability of embankments, by either of the modes of reasoning above referred to. The principles that direct the design of embankments to retain water are not those that apply to the calculation of the forces to be resisted or the means to overcome them, any more than breakwaters and harbor walls can be designed on mathematical principles. The whole question naturally turns on what slope the material composing the bank will stand at. If earth could be got to remain at a slope of 1 to 1, even though the embankment had no thickness whatever at top, it would be amply sufficient in weight to uphold the water in a reservoir. This, however, cannot be accomplished without the assistance of retaining walls, which would be found in most cases much more expensive than the additional earth required to increase the slope to the angle of stability; and therefore the section is so disposed that the earth shall stand both inside and outside the reservoir at such a slope as will be under all circumstances permanent. These slopes have been determined by long practice and by success and failure in pre-existing instances—that is to say, the limits have been laid down, for it is not to be assumed that all descriptions of earth will fall to exactly the same slope when exposed to the constant action of water or weather. Earth when subjected to the contact of water almost invariably loses a certain amount of its stability, and therefore it is usual to give the inner side of an embankment a longer slope than the outside. In most of the best existing examples the inside slope of the bank is either 3 to 1 or 2½ to 1, and it is rare to meet any departure from this rule. The outside slope may be designed at from 2 to 1 to 3 to 1, depending upon the character of the material, its power of withstanding the erosive action of the air, and the means used to protect the surface from being washed off or from crumbling away. In designing embankments, the impermeability of the earth is a matter that cannot be relied upon. There are, it is true, innumerable embankments now standing that have never allowed the escape of a drop of water from the reservoir, although no special precaution was taken to make them water-tight. Of these India abounds with examples, the introduction of a puddle wall being in the older embankments of very exceptional occurrence. The earth was merely dug out close at hand, and carried by the workpeople in baskets on their heads to where it was deposited, without any regard to the mode of disposing the material. The author has had occasion to construct a considerable length of levee, or embankment, on this simple plan for the protection of the country from the flooding of a river; and although, so far as he is aware, no flood has yet taken place to test the work, he has, from the study of existing examples, entire confidence in the result. The earth, so far as practicable, was disposed in layers, and before each was completed it was thoroughly consolidated by the tread of the workmen. It is not suggested that the puddle wall should be dispensed with in designing embankments, for the additional degree of safety, in most instances, will more than compensate for the extra expense it entails; but, in low embankments made of good retentive clay, the precaution of puddling is by no means a necessity.

Fig. 6.—No. 1.

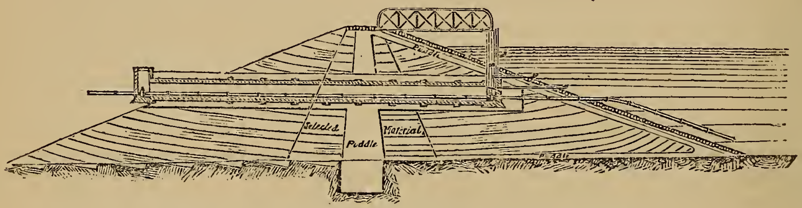


No. 2.

RESERVOIR EMBANKMENT.

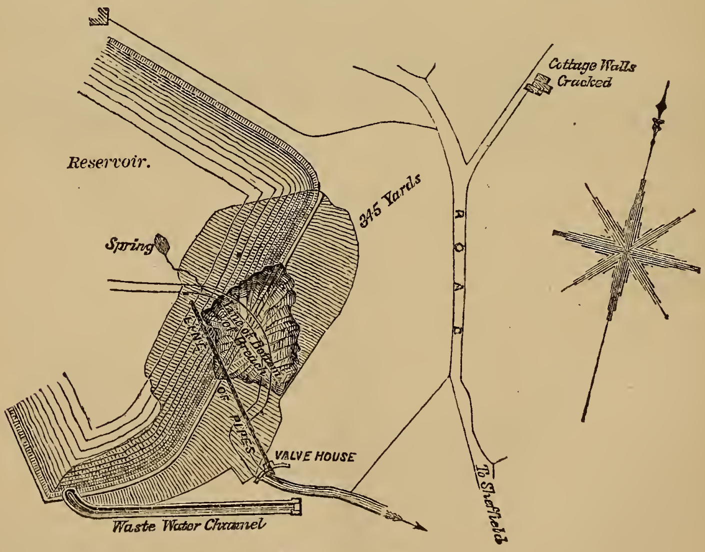
In most of the best examples of embankments in England, the practice adopted has been to carry up the earthwork in layers of 2 or 3 ft. in thickness, disposed in the manner shown in Figs. 6 and 7, and at the same time to construct in the centre of the bank a wall of well-puddled clay, the foundation of which is carried down for whatever depth may be necessary in order to reach an impermeable bed of earth or rock. It is not in all situations possible to procure earth exactly suitable and in sufficient quantity for the construction of an embankment, and consequently it is usual and advisable to dispose the best part of the material—that is, the most retentive of water—in juxtaposition to the puddle wall, as indicated in Fig. 6. In this example, the selected material is disposed equally at either side of the puddle; but, as its function is to withstand the admission of water, it would probably be more consistent, though less in accordance with practice, to place all the selected material on the inner side. The practice of excavating the earth for an embankment from the inside of the reservoir is one that should not be followed without caution. Removing so large a mass of material would, no doubt, give a considerable increase of storage room; but sometimes the bed of a reservoir is covered by a layer of impervious clay that is of immense value, and if this be cut through or removed, it is quite possible that a bed of porous material may be met with sufficient to allow the escape of water when it comes to be admitted. In specifying for the dimensions of the puddle wall, a sound rule for adoption is, that it shall have a thickness of 10 ft. at the top water-line and increase in thickness to the surface of the ground at the rate of 1 in. on each side for every foot of height. Before any excavation is commenced, it will be essential to make a sufficient number of borings to ascertain the nature of the soil beneath the surface.

FIG. 7.



SECTION OF EMBANKMENT—BIDDEFORD WATER-WORKS.

FIG. 8.



SHEFFIELD RESERVOIR.

It may here be mentioned that professional men are not apparently agreed as to the principles to be kept in view in constructing reservoir embankments; and this want of concurrence never was more apparent than in the discussion that followed the destruction of the Dale Dyke reservoir, near Sheffield. Fig. 8 shows a plan of the embankment site after the catastrophe. The bank was 95 ft. high, with slopes of 2½ to 1, and a top width of 12 ft. The puddle wall was 16 ft. in width at the ground-line, and tapered to 4 ft. at the top of the bank. This embankment, with the exception of the puddle wall, was composed of rubble stone and shale; an additional price having been given by the engineers to insure the use of the former material; which proves, at any rate, that this mode of construction was adopted on principle and not through ignorance or mistake. From the evidence given by the engineers of the company, it appears that it was, in their opinion, desirable that the inner part of the embankment should be permeable to water, because earth was much more likely to subside and slip than an open and less yielding material like stone. This mode of construction implies that the puddle shall be fully sufficient of itself to resist the passage of water, and that there is no necessity to relieve it of any part of the pressure against it. Of course, if a bank be composed of open work, every point in the face of the puddle is exposed to the full and direct hydrostatic pressure; and if at any point there is the smallest fissure or imperfection, the water has full power against it, and will, to a certainty, take advantage of such point to breach the dam. The assumption, then, of the constructors of this and the Agden reservoir evidently was that a puddle wall of some 25,000 sq. ft. of area was to be constructed without an imperfection of any kind, or a single weak point in the whole surface.

The obvious reason for employing puddle at all, in embankments, is to thoroughly close up any imperfection that may occur in the earthwork; it is in fact merely an accessory, and cannot be relied upon of itself to secure the embankment against destruction. If an embankment be constructed of good sound earthwork, properly executed, it is highly probable that the water may never penetrate half way through to the puddle wall, and probably, in the majority of examples, has not done so. Earthwork, however, is not always executed without imperfection; some decomposable material may be introduced, which, in course of time, dissolves, leaving a fissure; one part may be at first less consolidated than another, and, subsiding, lead to imperfection; or an embankment, be it ever so well constructed, may be burrowed through by moles, rats, and other vermin. It is to meet the first two of these sources of imperfection that puddle is used; and if, by such fissures as may occur in ordinary earthwork, water is admitted as far as the puddle wall, it can only exercise pressure against it at a few points, the puddle and earth being, in good work, so bonded and incorporated with each other that there is no space left for the water to occupy and press against the surface. Most who have read the account of the disaster that occurred in March, 1864, at Sheffield, will recollect how singularly conflicting the professional evidence on that occasion was. Some of our first engineers were ranged against each other in order to satisfy the public as to whether the failure of the embankment was attributable to bad engineering or to a landslip; and although the impression finally remained on the public mind that "there was not that engineering skill and attention to the construction of the works that their magnitude and importance demanded," the engineers were fairly divided in opinion as to the cause of the disaster. One section pronounced, without qualification, that the embankment gave way in consequence of a landslip, and entirely ignored the fact of the embankment being defectively constructed; whist the other gentlemen gave their verdict dead against the company, and their mode of constructing water-tight banks. The two diagrams, Nos. 6 and 7, may be taken as indicating the system of constructing embankments most generally approved of. The puddle, as will be observed, is carried up to the natural surface of the ground without any batter, and from that point slopes on each side to the top of the bank; on either side of the puddle is disposed, in concave layers, the most sound aud retentive part of the material, and outside of all comes the ordinary earthwork.

As a security against the eroding action of the water, and also against the inroads of vermin, the most desirable, as well as the most usual practice, is to pitch the whole of the inner face of an embankment with stone, carefully laid by hand. Neglect of this precaution has led to the destruction of many embankments in other respects securely constructed, and even when ample height of bank above the surface of highest water was provided. In all ordinarily inclement weather the disturbance of the surface of a reservoir amounts to no more than a mere ripple; but when the surface is of large extent, and a severe storm blowing, the waves produced are such as to cause reasonable apprehension, and, in fact, have, before now, overtopped the bank and cut it down, till the water flowed over and caused the destruction of the work. In most cases, it will be necessary to leave about 5 ft. between the level of the highest water and the top of the embankment, and never less than 3 ft.

A mode of construction not very generally used, but apparently consistent with reason, is that shown in Fig. 7, the embankment for the Bideford Waterworks. It consists in covering the whole of the inner face with a layer of puddle, with sometimes a layer of peat outside it. On some occasions it has been thought desirable to mix with the puddle a quantity of small stones or furnace cinders, by way of obstruction to vermin—a precaution that is by no means unnecessary. As an instance in point, the author is reminded of a masonry dam in India that had to be pointed every year regularly, because the fresh-water crabs in the reservoir found it convenient and promotive of their development of shell to appropriate the mortar to their personal use. The joints were cleaned out as effectually at the end of each monsoon as if the work had been done to order.

The preparation of the foundation for an embankment is a matter requiring some care. The soil, consisting of grass, roots, etc., and other matters of a decomposable nature, should be carefully removed over the whole surface to be covered by the bank, and if any porous material, such as sand or gravel, be present, it must be removed, until a compact and water-tight bed is arrived at. The bank must, in fact, be in contact with some sound and reliable material that will not admit the passage of water.

APPENDAGES OF RESERVOIRS.

Under this heading may be considered:

The whole apparatus for allowing the water to escape, including the pipes, the valve tower, and the culvert.

The waste sluices.

The waste weir or by-wash.

The most economical mode of discharging water from a reservoir is through a single pipe passing either through the embankment or immediately under it; but this plan cannot, under any circumstances, be recommended, though it is some times found in existing examples. It is open to several grave objections, the principal of which, perhaps, is that the failure of a joint under the embankment from unequal pressure, or from whatever cause, will probably produce the destruction of the embankment, or at any rate, entail a serious interruption to the supply, by the reservoir having to be emptied in order to repair the pipe. Buried in or under an embankment, a pipe is completely out of reach and out of view, and may be in a very defective state without its being possible to detect the imperfection.

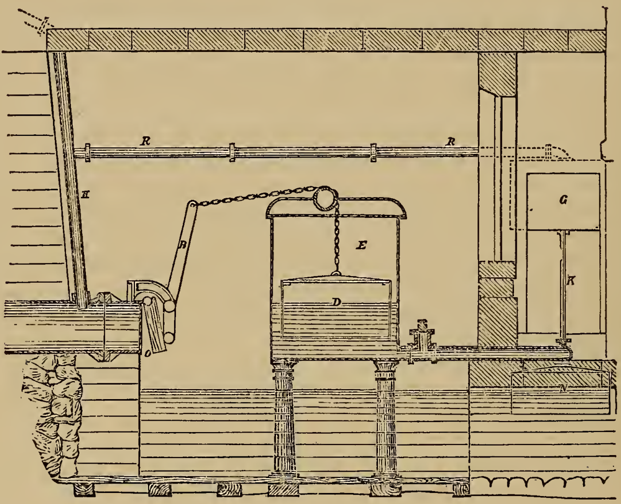
In order to secure the satisfactory working of a reservoir as a source of constant supply, it is esential that the outlet pipes, valves, and all other appendages for controlling and regulating the escape of the water, should be accessible for inspection and repair. The usual mode of accomplishing this is to carry the pipes out through a culvert of brick or masonry of sufficient dimensions to admit a man. This culvert communicates with the valve tower, as shown in Figs. 6 and 7, so that there is a complete communication between the outside of the reservoir and the inside. When unavoidable, the culvert is carried straight under the embankment in the natural ground; but the safest and most generally approved mode of construction is to bring the culvert round the end of the embankment, where it will be out of reach of injury from unequal settlement; a source of no small apprehension when either culvert or pipes alone are carried under the bank. Where possible, it is an excellent plan to run a heading through the solid ground, lining it with brickwork and puddling it, forming a tunnel entirely independent of the embankment. The principal objection to carrying either the culvert or pipes through or under the bank is their liability to fracture from the unequal settlement of the earthwork. It would appear that their liability to damage cannot with certainty be insured by any reasonable depth of excavation, and is, therefore, generally disapproved of by the best authorities.

In the best constructions the culvert is situated half way or two-thirds up the embankment, and in such case the outlet pipes for drawing off the water in the reservoir act as syphons when the water surface has fallen below the culvert. Fig. 6 shows a plan, as well as a cross section, of a reservoir dam designed for general application by Mr. Rawlinson. Here the bottom of the culvert is about 25 ft. above where the inner slope of the embankment intersects the ground at the lowest point. The syphon pipe is also shown passing through the culvert; the horizontal culvert is connected with a shaft inside the embankment, in which are placed the valves for leading off the supply from the reservoir. The valves are made to be closed on the inside by valve spindles and screws, and the inlet pipes are closed on the outside by plugs which can be applied from the top of the valve-tower. Thus the engineer has full command of the whole of the outlet works; all the pipes and valves are easily accessible and under perfect control, so that the supply can at any time be arrested for the repair of any derangement that may occur, even to the removal and replacement of all the pipes. The inlet pipes are shown in this example, as well as in Fig. 7, fixed at different heights in the valve-tower, the object of which is to draw the supply from the reservoir from points near the surface. The outlet pipe, passing through or under the embankment, may be connected on the inside of the reservoir by a flexible joint with another pipe of the same diameter, to the upper end of which is attached a float. This pipe is movable in a vertical plane, being controlled from lateral motion by the guide-posts. Such an arrangement admits of the water being drawn off from the surface, where it is least liable to be contaminated with impurities. Whatever arrangement be selected for drawing the supply off from a reservoir, the system of carrying the pipes, either with or without a culvert, through or under the embankment, cannot be sufficiently deprecated; they are, in such a position, beyond the reach of inspection, and, moreover, are very likely to induce leakage from the reservoir. It is usual to puddle carefully the culvert or pipes when carried under or through the bank, but, even with such a precaution, the water has under a considerable head a tendency to creep along the pipe, and, by soaking into the earthwork, may cause any one of the many evils that imperil and destroy embankments.

When embankments are not of great height, an exceedingly cheap and simple mode might be adopted for drawing off the water. This would be by laying a syphon over the embankment, as was done in the case of the middle-level drainage in Cambridgeshire, which syphon would at the inner side have a flexible connection with another tube having a float attached, as above described. Such an arrangement would apply in principle to heights not exceeding 30 ft., as the pressure of the atmosphere would maintain no greater height. In practice, however, the syphons cannot be worked with success at much above 20 ft., for it is found that after a short time, the flow becomes arrested by the collection of air in the upper part of the syphon, and it becomes necessary to pump the air out constantly, to prevent it from interfering with the flow, as it would do if not removed. It would appear a simple matter, where it is desirable to adopt a syphon, to utilize the power of the water flowing out for the purpose of getting rid of the air; it might easily be applied, through a small wheel and suitable gearing, to work an air-pump fixed at the highest point of the syphon, making the whole arrangement self-acting. The arrangement could be successfully applied to irrigation tanks in India, where the embankments are frequently less than 30 ft. Each leg of the syphon should be provided with a valve to retain the water, and when the supply was intermittent it would be essential to have an opening at the highest point of the syphon, and some appliance, perhaps an air-pump, for filling it with water in case of leakage.

To insure a constant discharge from a reservoir with a constantly varying head, several methods have been adopted; of these, one of the most ingenious is that used at the Gorbals Waterworks, near Glasgow. Fig. 9 represents a transverse section through the regulator-house, showing the arrangement by which the discharge is equalized. To the orifice of the outlet pipe, O, is fitted a square-hinged flap valve of wood, against which presses, by a friction roller, a lever, B, the arms of which are bent. To the upper arm is attached a chain that passes over a pulley, and is connected with a cast-iron cylinder or float, D, that stands in the reservoir, E, of slightly larger diameter. At the side of the entrance-door of the building is placed another cistern, G, of cast iron, closed at top, and communicating by a pipe, R R, with the vertical pipe, H, which is in connection with the outlet pipe, and passes up the slope of the embankment, to carry away any air that may accumulate in the main. The cistern, G, is connected with the reservoir, E, by a pipe, K, which supplies water to float the cylinder, D. Now, it is evident that the discharge from the reservoir will be regulated by the position of the lever, B, and this again will be controlled by the height of the float, D. To regulate this height the supply from the cistern, G, must be self-adjusting, or be regulated by the amount of water flowing away. The float, N, has attached to it a spindle, on which are fixed two double-beat valves that work in the vertical part of the pipe, K, one of which admits water from the cistern, G, into the cylinder, E, and the other allows the water to escape from the reservoir, E. Now, if the surface of the water upon which the float, N, rests should rise above the proper level, the float forces up the spindle, closing the supply valve from the cistern, and at the same time opening the lower valve. Thus the supply is cut off and the escape opened, enabling the float, D, to fall. The subsidence of the float closes more or less the flap valve, and checks the discharge, in consequence of which the surface of the water falls, and with it the float, N, which consequently opens the supply valve, and again admits water into the cistern, E. Thus an almost perfect equality between the consumption and the supply of water is preserved. It would appear that the same effect could be produced by connecting the lever directly with a float on the surface of the water, but such an arrangement would only apply when the pressure against the flap is trifling.

Fig. 9.



It is essential that every reservoir should be provided with some means of getting rid of the excess of water that flows into it, and whether this provision be made by a waste weir, sluices, or waste pit, it is one that should not be omitted. The most advantageous position for a waste weir will generally be at some point remote from, and entirely unconnected with, the embankment, and occasionally a natural depression in the ground, as shown in Fig. 4, will afford remarkable facilities for the construction of an escape. The level of the crest of the waste weir with reference to the top of the dam will require to be carefully adjusted, the minimum difference of level being 3 ft., and the maximum about 10 ft., depending on varying circumstances. The height of the waste weir will, of course, regulate the top water level in the reservoir; and this must be fixed with regard to the probability of the embankment being overtopped by waves. The circumstances influencing the height of the waves in a reservoir are the extent of the water surface, the depth, and the amount of exposure to or shelter from wind, all of which will vary with each particualar case. Under ordinary circumstances, the height of the top of the embankment above the crest of the waste weir should be for

an embankment 25 ft. deep, 4 ft.
" 50 ft. " 5 ft.
" 75 ft. " 6 ft.

and for greater height of embankment the difference of level may be proportionately increased.

When the configuration of the ground does not afford any facilities for the construction of a waste weir after the manner described, sufficient provision for the escape of the overflow is made through a waste pit. This waste pit, or tower, is generally a circular structure built over the outlet culvert inside the reservoir, and serves equally for access to the valves and for the escape of the flood water. With regard to the capacity of the waste weir or waste pit, whichever be adopted, it will be necessary to make ample provision for the discharge of the sudden accessions of flood water that reservoirs are subject to, and which so seriously imperil their safety. To provide for this there is an empirical rule amongst engineers that is supposed to suffice for the most urgent contingencies. It states that there shall not be less than 3 ft. of length of overfall for every hundred acres of gathering ground, but it is obvious that to proportion the length of the waste weir to a given area of country in all cases would be unreasonable.

The discharge over the weir will not depend only upon the quantity of rain falling on a certain area of ground, but also on the extent of the reservoir as compared to the gathering ground, and on the flat or precipitous character of the basin. The only safe mode, then, of proportioning the length of the escape will be to ascertain with exactness what the discharge of the stream or streams flowing out of the reservoir was during the greatest known flood, and then fixing upon an arbitrary depth for the water to flow over the weir, say 2 ft. or 3 ft, to calculate what length of overfall will suffice for the discharge of the excess water. In India, where large waste-weir accomodation is essentially necessary, while it is equally a necessity to save every gallon of water that is possible, it is a common practice to form a temporary dam, of earth and sods, on the top of the waste weir; this serves to pond up some 3 ft. or 4 ft. of water over the whole surface of the reservoir, and does not imperil the security of the works. In times of heavy floods the water rises and overtops the temporary dam, and no sooner does so, than the whole is carried away, and the water in the reservoir quickly subsides.

In works designed for the supply of towns, it is sometimes necessary to make provision to arrest the entrance of flood-water into the reservoir, as the streams may come down charged with large quantities of matter in suspension that would injure the purity of the water for domestic consumption. These streams may be diverted and carried round the margin of the tank past the dam, and can be admitted into the channel of the stream, or be utilized for mill power. On the Manchester Waterworks are constructed across the mountain streams weirs of an ingenious design, for the purpose of separating the flood-waters from the ordinary flow. The dimensions are adjusted from observations of each particular stream, so that the discharge up to a certain amount will take place into the channel for the supply of the town; but when the discharge increases, and the water becomes turbid, it has sufficient velocity to carry it over the opening, as shown in the diagram, and flows down to the compensation reservoir for the supply of mill power.

In determining the dimensions of a weir of this kind it is first to be ascertained what the mean velocity of the water flowing over will be for a given depth of water, h, above the crest. The mean velocity, v, will be

$$v = \frac{2}{3} \times 8.024 \sqrt{h} = 5.35 \sqrt{h}.$$

If the vertical height of the crest of the weir above the point to be overleaped by the cascade be called x, the distance across will be

$$y = \frac{2 v \sqrt{x}}{\sqrt{2 g}} = \frac{4}{3} \sqrt{x h}.$$

Before concluding, it will be well to give a brief consideration to the causes tending to the failure of embankments. The foregoing remarks will, in suggesting the best mode of construction, have anticipated much that might be said on the subject of failures; but there are a few points, the recapitulation of which the importance of the subject demands.

There are unfortunately on record, accidents, if they can be so called, from the bursting of embankments, that if estimated by the loss of life attending them, are as appalling as anything within the memory of man. Thousands of human lives have been sacrificed to ignorance and false economy, as well as in some instances to natural defects that it would have been difficult to foresee.

The existence of springs on the site of an embankment is an undoubted cause for apprehension, and considerable care should be taken to carry all water from this source away, that it may not, as it certainly will if not checked, force its way between the surface of the ground and the seat of the embankment. In doing so there is every probability that the earth of the embankment will be washed out by constant trickling till a fissure is formed of sufficient dimensions to render the destruction of the bank a certainty, if the water from the reservoir should ever penetrate so far. As a provision against this source of injury, all springs found on the site of an embankment should be taken up and carried away in proper drains sufficiently and securely puddled. Thus the water is confined to a single channel, and has no tendency to soak into the earthwork and blow it up in endeavoring to escape. In embankments of all kinds the presence of water is a most serious evil, and one by which may be accounted for, some of the most extensive land slips that are on record. It is erroneous to assume that when water is the active element in producing disruption in an embankment or mass of earth of any kind, that it only acts as a lubricant between the surfaces in contact. The truth is, the bulk of earth is sensibly affected by the amount of moisture in it, as is seen in the subsidence of newly-formed railway banks when exposed to rain. If, then, a sufficient quantity of water find its way into the centre of a bank that has been put together in a comparatively dry state, it will rise and soak into the earth until at length what was a solid mass becomes semi-fluid, settles into a smaller space than it before occupied, and, as a consequence, will leave a vacuity above it. The inevitable result is the subsidence of the superincumbent earth; but instead of resting, as at first, on a resisting material, it floats, so to speak, on the semi-fluid mass underneath, and having little or no friction to overcome, slips away to a lower angle than it before stood at. Natural springs, therefore, whenever they occur, must be dealt with carefully and completely. Exactly similar effects to those produced by natural springs may result from the defective practice of carrying outlet pipes through or immediately under embankments. Be the pipes ever so well puddled, there will be a tendency to trickling along the line of their direction, and assuredly if this trickle makes its way to the centre of the bank it will carry mischief with it. It is true that springs are occasionally found issuing from the foot of an embankment, without after several years causing any appearances to justify apprehension. The Doe-park reservoir is an example in point, and though at one time fears for its safety were entertained, the embankment is still standing, and, so far as the author is aware, the spring is still trickling away. An engineer of eminence was called upon to report upon the state of the works, and gave his opinion that, as the spring came away without any earth in suspension, there was no mischief taking place, and that the work was in a safe condition. There is no doubt that embankments in this condition require to be narrowly watched, although the presumption may be that, having lasted for several years, they will continue in safety.

The empirical and unscientific mode of proportioning the length of waste weirs has proved before now a source of danger and destruction to embankments, from the space afforded not being sufficient to discharge the excess water without the surface rising to such a height as to top the embankment. To avoid risk, the stream must be gauged with great care, and the discharge calculated for the greatest known flood; and if with a given head the length of the weir be adjusted to discharge this amount, or a little in excess, there will be no risk to the embankment.

Regarding finally the whole subject, the danger that may result from careless or unscientific construction, the large outlay entailed in the establishment of storage works, and the benefit that may accrue from them whatever their purpose may be, the subject cannot be undertaken on merely rational grounds. Its successful application will rest alone on the study of the question in its scientific details, and an ample practical experience.

DISCUSSION.

Mr. H. P. Stephenson said he entirely agreed with the author as to the impropriety of carrying a pipe through the embankment of a reservoir. He would extend his objection to the passing of a culvert through the embankment. If the culvert were laid on the natural ground, they would avoid the risks pointed out by the author, either of the settlement from the joints of the pipe, or of the water creeping along between the material and the pipe. He believed that the true principle of construction for reservoirs was the placing of a good puddle dam in the centre, and on each side of this dam layers of earth well punned in. One reason why he should prefer the puddle wall in the centre was that there was less tendency in the puddle to slip in such a position than when laid on the slope.

Mr. Albert Latham agreed with Mr. Stephenson in his remarks as to the pipes and culverts; but he thought it was an open question whether the puddle wall should be in the centre of the dam. He had a strong opinion that it should be on the face of the dam.

Mr. Cargill said that he believed that the reason the puddle wall was not required in Indian embankments, referred to by the author of the paper, was that the earth seemed to have been thoroughly consolidated by the continual trample of people upon it. That thorough consolidation was the great point in all puddling, and it was on that account that specifications were generally so stringent as to the thickness of the layers of the puddle. As to the position of the puddle wall, he could not see the particular value of having it in the middle of the dam, and he thought that a far better place for it would be the face, because the object of the puddle wall was to prevent the infiltration or the escape of the water. This could be effected by puddling the whole slope right down to the permanent strata. The puddle wall was not required to promote the stability of the dam. The question of putting pipes or culverts under the dam required more consideration. It was alleged that the putting of a naked pipe through the dam of the Bradfield reservoir was one of the causes of its bursting. In some very large waterworks now being constructed in Dublin there were two distinct sets of main pipes, and they were laid in two large culverts at the bottom of the dam. The culverts were large enough for a man to walk upright in them. If the foundation were well looked after, there would be no fear of the arch or dome of the culvert giving way in consequence of any inequality of pressure above it, as, if properly constructed, an arch would stand any amount of pressure short of what would crush the material.

Mr. Baldwin Latham said he could not agree with Mr. Jacob that a dam could not be constructed from theoretical deductions; for unless regard was paid to theoretical considerations there might result either a deficiency of strength or a waste of material and labor. In the dam shown in the drawings, and designed by himself, the pipe did not run through, but on the outside of the dam, on the solid ground. It was a well received opinion among engineers that if you had a pipe or culvert running through an embankment, that pipe or culvert would be unsafe. He believed that well made and properly tested pipes were quite as safe as culverts when in the solid ground. A pipe was simply a small culvert made of iron instead of brickwork. In cases in which there was a tendency for the water to creep along the outside of the pipe, that might be stopped by having projecting flanges on the pipe. The same creeping of water might take place along a culvert as along a pipe. With regard to the slope of a dam, the inside slope should be greater than the outside slope, because the greater would be the stability of the dam, and the water would have less destructive effect on the dam; he had effectually prevented leakage by the use of socket-pipes. The square projection of the sockets was alway presented to the reservoir, and the pipes were laid in the virgin ground. It was very bad practice to lay the pipes in made ground, and especially through a dam. Pipes laid under a dam should be tested under pressure after being laid and before being covered up, so that any defective joint might be discovered. In cases in which he had laid pipes through dams, they had been so tested, which resulted in good and effective work; but he was bound to say that, if the pipes had not been tested *in situ* the result would not have been satisfactory.

Mr. Schönheyder said that Mr. Jacob had said that wherever springs occurred they should be well carried away. He (Mr. Schönheyder) wished lo know how a spring was to be prevented from diffusing through the earth.

Mr. Hendry said that he had seen pipes which were laid through embankments, but had never seen one that was perfectly tight. It was almost impracticable to make it so, owing to the continuity of the puddle being disturbed at the point where the pipe passes through.

The Chairman asked what was the largest diameter of pipe Mr. Hendry had seen used.

Mr. Hendry replied that the largest was 18 in. He had heard of several methods being tried, but he did not think it was possible to prevent leaking, more or less, from the reservoir along the outside of the pipe. He should like to be informed how it was possible to connect the puddle with the pipe; if the pipes be laid in the natural ground below the foundation of the embankment, then there is no fear of leakage, provided the pipes are properly laid.

Mr. Jacob, in replying to the discussion, said, that in the opinions that had been expressed there were but few points of disagreement with those that he himself held. He could not agree with Mr. Latham in his belief that embankments could be calculated on mathematical principles. In order to deal with embankments theoretically, they must be regarded as rigid masses, and be assumed to rest upon a horizontal plane. It could be shown mathematically that a rigid body of the same specific gravity as ordinary earth need not present the same section as is usually given to embankments, in order adequately to resist the pressure of water. A right-angle prism with the hypothenuse resting upon the plane would be quite sufficient to resist the pressure of water, even supposing the surface of the water to coincide with the upper edge of the prism. The reason of giving long slopes to an embankment is discoverable from the fact that banks, when exposed to the action of water, are found to waste and slip away to such an angle as will withstand the action of the water. The chief reason of the failure of embankments is the infiltration or soaking of the water from the inner side, which renders the material semi-fluid and causes it to subside into a smaller space than it originally occupied. The superincumbent mass then sinks and allows the water to overtop the embankment. The earth used for making embankments in the Deccan and in parts of the Madras Presidency in India is of a most suitable quality for the purpose. It is what is called "black soil," being very dark in color, and of a highly argillaceous character. The color is, no doubt, due to the presence of carbon. The clay makes most excellent puddle; but, no doubt, the consolidation produced by the tread of the work-people is the real secret of the earth resisting the pressure of water so successfully as it does. In North America, the levees for protecting the country from flooding by the Mississippi are sometimes constructed simply of sand; and are found, for the most part, sufficient for their purpose. As regards carrying away springs from the seat of an embankment, there is no difficulty in ascertaining where they exist when the ground is laid bare, as they are generally well defined streams. Before the earthwork is commenced it is necessary to construct drains of masonry, or brickwork, or to lay iron piping to carry away the water clear of the work.

The Chairman said that the paper of Mr. Jacob was a very interesting one, and the subject was one which, during the last year or two, or, he might say, within the last week or two, had commanded the attention of the whole body of engineers. Last session a special Act of Parliament was passed that all reservoirs and embankments should be constructed to the approval of the Board of Trade. The subject of irrigation in India, which was alluded to in the paper, was one of vital importance. There was no question that the only means we had of irrigating that country in an efficient manner was by the construction of reservoirs.

LIQUEFACTION IN STEAM CYLINDERS.

From "The Engineer."

A correspondent has appealed to us for information on a subject of considerable importance. It will be seen from his letter, which will be found in another page, that he wishes to know to what extent liquefaction takes place in a jacketed cylinder. It is impossible to reply very briefly, and yet satisfactorily, to such a question; and we therefore propose to consider the matter here at more length than we could conveniently do in that column which is devoted to solving the various problems placed before us by our readers from week to week. What we are about to say may be taken in some sense as a sequel or appendix to two articles which recently appeared in our pages on indicator diagrams; indeed, it is impossible to properly answer our correspondent "Enquirer" without reference to a diagram.

Liquefaction, or, as it is popularly called, condensation, in steam cylinders, is a complex phenonemon—complex, that is to say, as regards its origin. It results from two causes: (1) the cooling down of the metal of the cylinder during the exhaust; and (2) the condensation due to the performance of work. It is possible to estimate the amount of liquefaction due to the second cause with great accuracy in any given case. To predict with certainty the amount due to the first cause is almost, if not altogether, impossible. We shall deal with the second case of liquefaction first, and we may premise that those who wish to see the problem treated in a strictly mathematical sense will do well to consult Rankine "On the Steam Engine," page 385, *et seq.* It is our purpose, however, to handle the question in a different way, so that the principle involved may be rendered as intelligible as possible to those who possess little mathematical knowledge.

A unit of heat is that quantity of heat required to raise 1 lb. of water 1 deg. Fah. in temperature. We speak here of quantity of heat, not because heat is a separate and distinct entity, as it was held to be under exploded antiquated theories, but because the word "quantity" expresses something different from intensity, which is alone measurable by the thermometer. To put this plainly, it will take twice as much heat to raise 2 lbs. of water 1 deg. as will suffice to raise 1 lb. of water 1 deg.; but the thermometer will show only a rise of 1 deg. in both cases. A pound of steam at atmospheric pressure contains in round numbers 1,147 units of heat; in other words, as much heat as would raise 1,147 lbs. of water 1 deg. Fah. Now, in the physical world nothing is to be had for nothing; and we cannot have work from a steam engine without loss of heat from the steam. A unit of heat represents 772 lbs. lifted 1 ft. high, or 1 lb. lifted 772 ft. high. In other words, a unit of heat is the equivalent of 772 foot-pounds, and as much work is done in raising 1 lb. of water 1 deg. as would suffice to raise the same 1 lb. of water bodily to a height of 772 ft., or say to three times the height of one of the water towers at the Crystal Palace. But 1 lb. of steam at atmospheric pressure contains 1,147 units of heat, and therefore represents 1,147 × 772 = 885,484 foot-pounds. Now a horse power is 33,000 foot-pounds per minute, and

$$\frac{885{,}484}{33{,}000} = 26.8.$$

In round numbers each pound of steam at atmospheric pressure condensed per minute, represents 27 horse power. An engine, therefore, working to 27 horse power, with steam at atmospheric pressure, must of necessity liquefy in its cylinder 1 lb. of steam per minute. From this there is no escape. If a jacket is employed, then the liquefaction may take place wholly in the jacket; or, as is usually the case, it will take place partly in the cylinder and partly in the jacket. But how much will take place in the jacket, and how much in the cylinder, depends on some dozen conditions, the influence of which it is impossible to determine beforehand, such as the thickness of the cylinder walls, the conductivity of the metal, the temperature of the steam in the jacket and in the cylinder, and so on.

Hitherto we have spoken only of liquefaction as regards steam of atmospheric pressure. But the amount of liquefaction is very little affected by the pressure. Thus, if the initial pressure of the steam was 85 lbs. on the sq. in., the total number of units of heat contained in 1 lb. of it would be in round numbers 1,182 instead of 1,147, a difference so small as to be practically unappreciable; and if the weight of steam condensed be independent of the pressure, it is equally independent of the point of cut-off, the ratio of expansion, and every other consideration. For each 27-horse power indicated 1 lb. of steam is returned to its original condition of cold water. This loss must take place, and in one sense it is not to be considered a loss, since it is the equivalent for work done.

It may be asked when and where the condensation takes place, but this point we shall not stop to consider. It is enough that in steam engines, as ordinarily constructed, it takes place in the cylinder. We have heard it argued that the liquefaction is caused by the expansion of the steam. Thus the temperature of steam at 85 lbs. pressure is 370 deg., while that of steam expanded to 15 lbs. above a vacuum, or atmospheric pressure, is 212 deg , and it is assumed that the fall in temperature causes condensation. But this is totally erroneous. A pound of steam at 85 lbs. contains as we have seen 1,182 units of heat, but 1 lb. of steam at 15 lbs. above a vacuum only requires 1,147 units to maintain it uncondensed; therefore, in expanding without doing work from 100 lbs. absolute—85 lbs. nominal—pressure, to 15 lbs. absolute pressure, 1 lb. of steam, instead of being condensed, will actually be slightly superheated, the difference between 1,147 and 1,182, or 35 units, being left free to operate in superheating the steam. If then steam is superheated in expanding without doing work, and if liquefaction takes place when work is being done, it is evident that the doing of work is the cause of liquefaction; and the amount of liquefaction must, as we have said, be determined solely by the work done, and not by the grade of expansion, which can only operate in the sense that the lower the grade of expansion the less will be the liquefaction due to the cooling of the cylinder, for reasons which we have often explained.

It must be clearly understood that the liquefaction due to work has nothing whatever to do with the condensation which ordinarily takes place in all steam cylinders. What this loss will be it is impossible under any circumstances to determine, except by actual experiment, save in the case of twin engines. Knowing the loss in one, we can say with some approach to truth that the loss in the other will be nearly the same. In all cases, the liquefaction due to cylinder cooling is very much greater than that due to work done. We believe that there is no recorded instance of a trustworthy character in which less than twice as much steam as is thoretically necessary to produce a given power has been used; and only in very good engines indeed do we ever find the weight of steam condensed less than three times as much as would suffice theoretically to develop a horse-power per hour. This is the great defect—the crying evil of the steam engine—and it does not appear that it can ever be overcome until some genius apparently yet unborn supplies us with a non-conducting cylinder.

ON THE INFLUENCE OF TEMPERATURE ON THE ELASTIC FORCE OF CERTAIN FORMS OF SPRINGS.*

By Mr. F. H. WENHAM, C E., Vice President R. M. S.

From "The Engineer."

At the last meeting of the British Association* at Brighton, Professor Philips brought forward some remarkable facts relating to the aneroid barometer, showing that in new instruments a permanent set, or difference of indication, is caused by high temperatures, and that a number of alterations of heat, extending over some period of time, are required before the elastic plate becomes completely seasoned, so to term it, to insure regularity in the indications.

It has been long known to meteorologists that thermometers, though accurately graduated at first, acquire after a few months, an index error of sometimes two or three degrees, arising from a tendency of unannealed glass forming the material of new bulbs partly under tension to return to a state of equilibrium with a consequent alteration in capacity, thus showing the propriety of seasoning the instruments by repeatedly subjecting them to the extremes of temperature they are capable of bearing before finally setting them to scale. In connection with instruments for measuring and regulating time, force, or temperature, some of the properties of elastic plates, rods, or springs, may be first mentioned. Their value in these applications depends upon the law that the spaces or degrees of motion are exactly as the forces; that is, if a force of 100 lbs. be applied, each space due to this division of the scale will indicate 1 lb. This law relates only to bodies of certain form, such as a bar supported at one or both extremities, weighted at the end or middle; in a rod subjected to torsion; to a spiral spring either extended or compressed (the opening or closing of the coils in either

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* British Association, Section A.

case is virtually a torsion of the wire). This property of equality of force and motion is also identified with the time in which those motions are performed; and the last law follows upon the preceding one, for if symmetrical forms of springs whose deflection indicates equal degrees of space be set in vibration, such as a rod supported at one or both ends, like the tongue in a musical-box, the wire of a piano, or the metal plate of a gong, it gives the same note, whether the vibrations are great or small, proving that the motions are performed in equal times. Such springs are termed isochronal. The flat or spiral coil springs used for the balance wheels of watches and chronometers are not strictly isochronal, for in winding up the spring, as the tension increases, equivalents of force are not represented by equal spaces, which diminish. On the other hand, when the spring is unwound within certain limits the spaces become slightly greater. An instrument was used by the author for testing these points, consisting of the five inner coils of an ordinary watch mainspring fixed to a central pivot, having a pulley round which a thread was wound with a receptacle at the free end for weights. The outer end of the spring was fixed in the same way as the balance spring of a watch; the spring and its attachments were on one side of a metal plate, the other having a circular dial suitably divided. The forces were indicated by a hand attached to the end of the pivot. Within the limits of one revolution only the forces, both in winding and unwinding, were so nearly equal for all divisions that a difference could scarcely be determined, and the slight variation that takes place in the arc of vibration in a well-made timepiece or chronometer with an equalized maintaining power, would render the difference incalculably small, and the balance springs, whether of the archimedean, spiral, or flat helix form, may be considered as practically isochronal. According to the test of additional force in winding, the vibrations should be quicker with increasing arcs; but this tendency is probably nearly neutralized in the opposite extreme, where in unwinding, the forces diminish with an opposing compensating loss of time.

For the purpose of ascertaining the influence of heat on the elasticity of the spring at equal degrees of tension within one revolution, the back of the dial plate was enclosed in a metal box. A thermometer was set so that the degrees could be read off on the projecting stem. A gas jet was brought under the arrangement, which formed a closed oven with the interior, presumably of uniform temperature at the various trials. The spring was first wound by weights to half a revolution, the thermometer indicating 80 deg.; as the mercury rose to 200 deg. there was a visible forward movement of the hand indicating a gradual loss of elasticity. At 300 deg. the deflection was 1½ divisions beyond the 100 into which the dial was divided. At 400 deg. the loss was 3½, at 500 deg., 5½. On allowing the whole to cool down to 80 deg., the hand returned or fell short of the first indication before the application of heat by three divisions. The spring was now weighted to the entire revolution. At 300 deg. the deflection increased by three divisions, at 400 deg. to seven divisions, and at 500 deg. to eleven divisions. On returning to the normal temperature of 80 deg. the spring had taken a permanent set, or went beyond its first deflection to the extent of five divisions, showing that at this temperature and degree of compression the loss of elasticity was 5 per cent. of the total force.

These experiments only served to demonstrate the principle, and were not continued, because the arrangement was too complex to be exact. The friction of the pinion is a source of error; and it appeared to be difficult to establish a law from results obtained this way. Such a law or principle would be important, considering that the compensation given to the balance of chronometers is almost entirely for the purpose of counteracting the loss of elasticity by use of temperature in the coiled spring itself, and so by a decrease of central force increasing the rate of the vibrations according to a known regular law, to compensate for the weakened force of the spring in an irregular and unknown law. The mode of conducting the experiments was now varied so as to represent the elastic plates of an aneroid barometer. Two pins were inserted 13 in. asunder in a slab of slate. Acrose these the materials to be experimented upon were laid. They consisted of a bright hard drawn steel wire, one of brass, and a thin strip of window-glass; these weighted in the middle gave divisions equal to the forces. A thermometer was placed with its bulb just above the middle of the bars to be tested, so that the temperatures could be easily read off. A stand supported the slate tablet, which was approached more or less to an ordinary open fire as required, the radiant heat giving a satisfactory even temperature. The deflections were ascertained by a pointer on a finely divided scale. The results of these trials can only be taken approximately. As there was no arrangement for multiplying the motions, the fine divisions were exceedingly difficult to read. In the steel rod with various weights suspended the ranges of deflection increased from the temperatures, 100 deg., 200 deg., 300 deg., 400 deg., and 500 deg., in the irregular ratio of 3, 4, 6, 10, 18, the total deflection amounting to four tenths of the range of compression before the application of heat. When cool, with the weights suspended, the rod did not return to its first position, but had taken a permanent set equal to one-third of the range. The brass wire tried under similar circumstances was comparatively so devoid of elasticity that the first few degrees of heat caused a visible deflection, which continued nearly equally till the 500 deg. was reached; the wire was then deflected a distance of two-thirds the normal range of compression. The glass rod under the same conditions at 500 deg. increased the distance by near one-seventh of the range of compression, but the elasticity due to a strip of thin window-glass is so small that the ratios of the temperatures before-named could not be clearly ascertained, and the permanent set when cool amounted to only one-fourteenth of the compression, showing an advantage in the elastic properties of glass when tried this way visible, if not clearly measurable.

It appeared that experiments conducted according to this plan could not satisfactorily determine a law, even if the deflections were indicated by a dial movement, for multiplying or giving ranges of greater visibility, as every moving part must be a source of error liable to derangement from heat. The experinents were, therefore, next performed in a much more practicable and manageable way, by which short strips or springs of the elastic material of only 1 in. long were used. These were firmly secured at one end to a small clip block, in which a light steel wire 12 in. long was screwed, the wire and spring in one line. This served as a steel-yard and indicator upon which weights were suspended. The free end of the spring was passed into a slit cut in an adjustable block of brass contained in a piece of tube 1½ in. in diameter, closed at the top and bottom, but having a passage in the side sufficiently wide to allow the introduction with free play of the wire and attached spring into the slit. A thermometer was slid down through the lid, with the bulb close to the spring, for indicating the temperature of the interior when heated by an external gas jet. The first experiment was with an inch of ordinary tempered watch spring; the end of the rod or pointer was very sensitive, and of course gave any desired range according to the weight attached. This was adjusted for a space of 6 in., which represented the extent of compression at which the temperature was applied. The four intervals from 100 deg. to 500 deg. caused deflections in the ratios of 13, 16, 40, and 52. The total heat deflection amounted to 2½ in.; the return when cool was ½ in., leaving 2 m., viz., the spring had become permanently deflected one-third of the range by the application of the last 500 deg. The second experiment with the same spring unaltered and ranging 6 in., presented a remarkable contrast. Starting again from 100 deg. with the same temperature as before, the corresponding ranges were in the space proportions of 3, 5, 9, and 15, at which last, or 500 deg., the deflection was only one-tenth of the compression instead of one-third as before; and on cooling, the spring returned so far that the permanent set was only two-tenths of an inch or one-thirtieth part of the primary range. The experiment repeated gave exactly the same result as to the proportionate distances of deflection, but the set became rather less. It may be questioned, however, whether this could be entirely eliminated by numerous repetitions, for a temperature of 500 deg. is sufficient permanently to impair the elasticity of steel springs. The next trial was with hard crown glass, as this method enabled thin threads of that substance to be used, having any desired degree of elasticity according to their tenuity. The end of a narrow strip one-tenth wide was drawn into a thread through a gas-flame, and the other end pointed to show the position on the indicating card. With this brittle material long sweeps could not be secured, the range of compression was only 1 in., with the same temperatures as for steel the deflection at 500 deg. was one-eighth of the compression, and the distance for each allotted temperature formed about a similar irregular distance of division as for steel, with a permanent set in the same proportion, showing but little advantage in favor of glass as tested this way. An inch strip of strong hammered white metal, or German silver, was now tried, which by this operation had become exceedingly elastic, and was tested just the same way as the steel. This metal was very sensitive to the effects of heat, the first few degrees showing a visible drop of the index point. At 500 deg. the deflection amounted to just one-half the range of first compression, and on cooling, the permanent set was shown to be one-third of the same distance; but the remarkable distinction was that the divisions were nearly equal, the space at the last 500 deg. being the same as the first. This experiment was repeated with the now partly seasoned spring; the deflection for the extreme of 500 deg. was only one-fifth of the range, having equal divisions as before, and the permanent set one-seventh of the same distance. Experiment third, deflection one-eleventh part of range, set one-eighteenth; fourth experiment, deflection one-eleventh, as in the last set, one twenty-seventh heat spaces, or divisions still equal. Such were the practical results of these trials, which, though sufficient to illustrate a condition, are not numerous or varied enough to establish a law. The author hopes to continue them under different circumstances, such as thin rods submitted to torsion with the test of heat at varying degrees of force. A comparison of numerous data might develop a definite law very useful to the practitioner in the various instruments to which it relates. The most singular result is that indicating that a metal whose elasticity is obtained by condensation of the material should lose it equally with equal degrees of heat, while steel, in which elasticity results from fire in the process of hardening and tempering, obeys a different rule. Possibly this may give some reason for the fact that a gold alloy has been used by some chronometer makers in lieu of steel balance-springs, probably rendering a secondary compensation less necessary. The author has seen such springs in use, but has never heard it stated why they have been applied. It is a long established fact that if a chronometer is adjusted for extreme temperatures it will be incorrect for mean ones, or the converse; and to meet the irregular way in which the elasticity of steel is affected by heat, this law of elasticity in relation to temperature, once ascertained, might determine the path in which the compensating weight should traverse, so that a due proportionate decrease of central force might counteract the elastic loss of the spring by increase of temperature. The author must state that the indications with glass were far less definite; but to demonstrate how great and sudden changes of temperature may affect a thermometer the following experiment was tried :—The bulb of a thermometer was suddenly plunged into melted lead; the mercury instantly darted down far below zero ; the action was so quick that the point could not be ascertained. This was caused by the sudden expansion of the bulb by heat before it reached the mercury by conduction ; this then began to rise very rapidly, and before it had arrived at the top of the tube the bulb was withdrawn. This requires adroitness, for, as we all know, the instant that the mercury touches the top the bulb will burst. This must be greased before immersion in the fused lead, otherwise a film of the metal will adhere and retain sufficient heat to carry the mercury to the top, with a consequent fracture. A thermometer treated in this rough manner afterwards showed an index error of six degrees, the mercury having risen to this extent; but after a few days the equilibrium was partly restored, and the error remained permanently at 3 deg.

As a comment on the above experiments it may be urged that a source of inaccuracy would arise from a vertical force acting on a lever varying in length, but after the deflecting weights were suspended the arm was brought so far above the horizontal line as to divide the remaining small arc due to the heat deflection. The sine of the chord for this in a radius of 12 in. was too minute to make any difference in the force of leverage worth noting.

Further experiments are required, but the present ones show directly in all instruments for indicating and registering weight, pressure, temperature, and perhaps, time, by means of the law of elasticity, that the material, whether of steel, glass, and particularly any metal in which this property is obtained by condensation or hammering, the importance of subjecting them to an excess of temperature before the graduations and adjustments are made.

PROPORTIONS OF PINS USED IN BRIDGES.

Communication from C. H. BENDER, C. E., to the "Railroad Gazette."

Your edition of November 1st contains a criticism on my paper referring to proportions of pins used in bridges, which was published in "Van Nostrand's Magazine," and reprinted as a little volume of Van Nostrand's "Science Series."

The said criticism I believed not to be one likely to give a just or even correct abstract of the paper, and therefore in the following I wish to make a few remarks towards defending my investigations:

The paper consists of three parts, of which the first intends to furnish a "sufficient" idea of the differences between maximum and minimum pressure exerted on the bearing surface of a pin. The second analyzes the shearing strains acting in the cross-sections of the pins; while the third one refers to the maximum tensile strains caused by flexure. This last part is the one by which the dimensions actually are determined, and forms the centre of the investigations, since the two previous ones are only secondary in their importance.

The experimental researches of the English engineers had failed to recognize the influence of the thickness of the eye-bar on the strength of the joint. Experiments had been made with wide and thin eye-bars, and from these a general rule had been derived, thought to be correct for all kinds of bars, fixing the diameters at $\frac{2}{3}$ or $\frac{3}{4}$ of the width of the bars. This rule in more than one case has caused misapplications by which the joints were built by far too weak, and on page 47 of this little book, in a couple of rough examples, it has been shown what great danger there lies in the use of this rule. The series of diameters finally adopted in this little book, for a number of forms of bars, only for very flat bars approaches those obtained with the English rule; while for bars as they are generally used in well-designed American bridges much greater diameters had been found.

American bridges in principle differ from those used in Europe by not giving up that most direct mode of forming joints which had been in use previously to the time when the English engineers introduced the rivet, since which the pin connection has been abandoned by the majority of English engineers. The establishment of the practicability of wrought iron bridges with rivet connections, in consequence of the success of the Britannia Bridge, had led Europeans in a channel from which only very lately and in consequence of the American success with pin connections—thus far only in Germany—they have commenced to return; while the insufficient success of badly-proportioned pin-bridges, especially in England, still holds in captivity the judgment of a great number of European engineers.

The importance of a careful study and of proper porportions of pin connections is therefore most obvious, and it was the recognition of this fact which led me to the somewhat intricate and time-absorbing investigation, the results of which were condensed in the little book published by Mr. Van Nostrand. It is admitted that not all of its contents are of an elementary character, but that it requires some study, and that it supposes familiarity with the higher theory of elasticity up to its present level.

I am charged with an unlimited confidence in the theory. No mistake could be greater than this. The little book itself contains the strongest proofs against such assertion, and these, strange enough, are quoted in the criticisms. Thus, on page 15, proper experiments are desired to determine the influence of play in pin holes, which was expressly stated on pages 5, 6 and 15 not to have been drawn into calculation, and whose introduction would have led to much greater differences of pressure, and also to greater diameter than those found under the adopted suppositions. On page 40 I have again stated the necessity of proper experiments in order to determine the durability of forged, riveted or machine-worked parts for each class of materials.

We have but lately commenced to arrive at some reliable ideas as to the real value of the material of construction. The gentleman to whom I must consider to be due the greatest thanks in this respect is Mr. Woehler, some of whose experimental results are quoted on page 38 of the little book. The reason why this gentleman was more successful than others lies in the circumstance that he is at the same time as well versed in the theory of elasticity up to its higher branches as he is a practical mechanical engineer of great experience. In order to make successful experiments, before all it is necessary to know what should be experimented on, and in a good many cases the elementary school knowledge is not sufficient to this end. The investigation, therefore, should precede the experiment, and not follow, as the author of the criticism asserts. If this critic does not place much reliance in the theoretical deductions of the character furnished year by year in voluminous books, he will find myself to agree with him perfectly. These are filled with an enormous amount of mathematical rubbish, and contain generally nothing but a great and uselesss quantity of common algebraic labor, which could readily be dispensed with. Theory of this class, indeed, has done a great deal of mischief. But it would be unjust to declare that it has caused all the numerous failures on account of following theories in "untried cases." Just as many grave errors have been caused by improper experiments, which are generally accepted with considerably less hesitation, and without the necessary examination of their suppositions.

On pages 16 to 24 of my paper I believe that I have clearly and conclusively proved that all those experiments which have reference to pins were not made in accordance with the wants of practice, and that its very results have led to misapplications.

I will add here something more concerning deluding experiments. The English experimenters believed that they had established that the modulus of elasticity of wrought iron was pretty nearly a constant value. But, on the contrary, the moduli of elasticity of wrought iron, on authority of experiments on many thousand eye bars, now members of bridges, are varying from 18,000,000 to 45,000,000 lbs. per sq. in. The supposition of a constant value of the modulus forms the important basis of the theory of continuous beams, which falls to the ground with that supposition. The proportions of the Britannia and the numerous other continuous bridges, therefore, cannot be considered as correct.

The connections of all European bridges are based on the results of experiments on a small scale on riveting, which for many reasons can be proved not reliable under the present practice. The results of such practice are apparent enough. Thus, for instance, riveted girders built according to those rules and arranged for actual use on the "Chemin de Fer du Midi," in France, when tested broke under 26,000 to 27,000 lbs. per sq. in. They deflected, inside of the elastic limit, three times as much as might have been expected from a theoretically perfect girder. The deflections of the Conway Bridge show a decrease of from 25 to 42 per cent. of the modulus of the iron used, proving again that the empirical rules derived from experiments on rivets made up to the ultimate strength did not give the expected results when tried in a manner nearly in accordance with the practical use.

The same insufficient result was obtained by Brunel's tests of a 66-ft. long plate girder, which broke under the calculated strain of 30,000 lbs. per sq. in. of net area. Also the experiments on pillars of the often-quoted English engineer Hodgkinson by American tests have been proved to be totally unreliable. (Compare Mr. Samuel Reeves' experiments on his columns.)

In my paper I have repeatedly pointed at the necessity of making experiments which will be congruous with the state of affairs in practice. Nobody would test a piece of cloth by putting it to its ultimate strength in a machine, for there are numerous other conditions to be filled in order to make a good and durable coat. And yet such a rough course is taken when it comes to try the qualities of a material of construction.

The author of the criticism, therefore, makes a too sweeping assertion when he thinks that experiments on the ultimate strength "at least seem to indicate the weakest part of a member or to indicate in what direction the correction should be made." As long as the experiment is analogous to the usage of the member, this is true; but there is nothing to prove that it must be so when the member is quite differently used. (With reference to pins, compare pages 23 and 24 of the little book.) Thus, for instance, Hodgkinson's experiments on compression to the ultimate strength seemed to prove that with compression lies the weak point of wrought iron, while, on the contrary, numerous experiments on impact prove that under repeated strains lower than the ultimate strength the tensile parts give way previous to the compression members. This is probably the same reason why bridges with cast-iron compression members in this country when failing did so by rupture of the tensile parts.

The author of the criticism also thinks it quite obvious that the pins should have been made strong enough, while there is supposed to have been great difficulty in bringing the eyes to the proper proportions. From what we know at present, this seems plausible enough; but actually it was not so. The engineers thought they could save metal by reducing the diameters of pins, proofs of which are the failure of the Crumlin Viaduct as first designed, and the failures and wearing out of many chain bridges.

Again, I did not think it worth while in my paper to speak about the very small and unimportant deviations of the elastic law inside of what is called the elastic limit, which is nothing but a harmless name, meaning the limit where those deviations commence to be of any importance, even in theory.

It is not a mere phrase when I asserted that the theory within the elastic limit is not less correct than the law of gravitation applied to the movement of planets. A very strong foundation for this assertion can be found on pages 38 to 41 of the little book.

Purely theoretical investigations, based on the general law of elasticity, under application of the very finest and most elegant analysis, have led Navier and others to conclude that each direct strain in any direction of a body must be accompanied with a negative direct strain one-fourth as strong as the first, but acting normally to it. By a series of not less acute conclusions, this law leads to the other, that the modulus of shearing elasticity is only two-fifths of the modulus of direct tensile or compressive elasticity, both of which in wrought iron and steel of good make are equal. Most interesting experiments of Regnauld and Wertheim have—notwithstanding the technical difficulties—proved that this law for wrought iron is correct within $1\frac{1}{2}$ per cent. (See page 35.)

Mr. Waehler has determined the true moduli for good iron and steel directly by tensile, transverse, and torsional experiments, and finds the ratio between both to be 0.39, while the theory gave 0.40. This is certainly a most satisfactory result. He has done more. He has tried the durability of iron and steel under impacts, exposing the materials to exertions of the same kind as is the case with railway car axles, and as is the case in bridges, and thus he found that torsional or shearing strains cannot be withstood as high as direct strains, and that the ratio of durability under both kinds of strains is as 0.793 to 1,000, while theory gives 0.800 to 1,000.

Now I do not deny that I hold this victory of the theory to be just as beautiful as the once so surprising confirmation of the law of gravity by the discovery of a previously calculated planet.

The question really at stake here is this: Are we at liberty to apply the established theory of flexure of plain beams to the calculation of the strains acting on bridge-pins? Relying on the confirmation of this theory by a most abundant number of well-conducted experiments on transverse strains, I answer this question with a decided yes, so much the more since a pin—as stated on page 46 of the little book—is a piece of iron unimpaired by workmanship and fire. Certainly this is admissible a hundredfold more than the application of the theory to the punched and riveted compound beams, girders and bridges, of varying sections, depths, moduli, etc. In the criticism I do not find any doubt as to the application of the elementary theory of flexure to the determination of the maximum tension of a pin, by which the diameters actually were determined (from page 42 to 47), and whose results do satisfactorily coincide with the best present practice, nor has any fault been found with the second part of the paper.

The suspicion which is thrown on the usefulness of my labors only refers to its first part, which is the least important of the three, and has only for its purpose to give a sufficient idea of the distribution of the pressure over the pin-bearing, under the expressly stated supposition that no friction is taken into account, and that the pin accurately fits the hole. It is also expressly stated that under this supposition the diameter of the pin would be found a little too small.

Under this supposition the pressure on the semi-surface of a transverse slice of a pin is actually uniformly distributed over the diameter, and, if it were not so, it would only be necessary to determine the ratio between the maximum and minimum pressures on the bearing surface.

The deviation of the maximum pressure found under my supposition from that of a pin with play could not be unknown to me, since, as far as I could find, my teacher, Professor Grashaf, about a dozen years ago, was the first who made similar investigations toward the determination of the proper diameter of expansion rollers used in bridges.

When the critic says that on page 6 the assumption of uniform transverse shearing stress underlies my analysis, there must certainly exist a misunderstanding, and he means to say that the pressure on the semicircumference of a bearing circle is supposed to be uniformly distributed over the diameter.

There is also a misunderstanding on the part of the critic when he thinks that I had proved that there is no shearing strain on the surface of the pin. In fact, there is but one point of the circumference of a section through a bearing-pin which is free from shearing strain.

Again, it is objected and said that in order that the transverse shearing should be uniformly distributed, the pin must fit the bearings. This remark is not correct; for even when the pin does fit exactly, the shearing strain will not be uniformly distributed. Again, shearing strain and pressure were substituted one for the other.

In the investigation under No. 1 of the little book, one part of the theory has not been taken up at all, and this is not noticed in the criticism: namely, the deflection of the pin due to the shearing strain. By this the maximum pressure on the bearing surface would have been found greater, but the amount can practically be considered as offset by the relief caused by the longitudinal pressure due to flexure. Namely, in the criticism doubt is expressed as to how the maximum pressure is—if at all—modified by the tension of flexure above. This tension, indeed, is without influence, but not so the longitudinal pressure below, which, according to Navier's law (see page 34) causes a vertical tension, which reduces the pressure.

Under all circumstances, the diameter of pins found, under the suppositions of the little book (page 6), would be theoretically too small, when the pin does not fit exactly, and the given dimensions therefore must be considered as minima.

Finally, it may be allowed to add, in answer to one other remark of the criticism, that the influence of the transverse stiffness of the long and thin eye-bars is practically too small to be considered in the calculation; and since there are so many irregularities of manufacture, this little assistance is but too welcome.

On the whole, it is believed that notwithstanding the difficulties of exact examination of even the very simplest phenomena of elasticity, the first part of my investigation has at least done this good—that of giving to many an idea that the bearing pressure is not at all uniformly distributed over the cross-section; that even with diameters of pins as large as those given, we still have to deal with pressures probably as high as 15,000, and even 18,000 lbs. per sq. in., according to the more or less high degree of perfection of manufacture.

If I could hope by my paper to have caused a number of experiments to be made on this subject, such as recommended on page 15, the labor spent on this investigation I would consider as well recompensed.

EXPLOSIVE COMPOUNDS.

From "Engineering."

MM. Roux and Sarran, engineers to the Government department in France for the manufacture of gunpowder, have recently made experiments on the pressure of the gas liberated by the combustion of various explosives. Applying the well known laws of Mariotte and Gay Lussac to these experiments, they ascertained the volume of the gaseous products reduced to 0 deg. Cent., and a barometrical pressure of 0.76 metre, or 30 in. English. The apparatus they employed was an eprouvette, of a cylindrical shape, made from forged iron. and having an internal diameter of 0.022 metre, and 0.3 metre in height. This eprouvette, in which the combustion of the powder was effected, was closed at one of its extremities by a screw-tap, traversed by an insulated wire, which was employed for the purpose of igniting the explosive under examination, and furnished, at the other extremity, with an adjutage, screwed into the socket of a manometer. This manometer has a differential piston, the pressure exerted on the small base (of which the area equals $\frac{1}{100}$ of the larger base) of the piston being measured by that exerted on a larger base by a column of mercury, reduced in the proportion of the two bases, and expressed in millimetres. A known weight of powder being placed in the eprouvette and ignited, the mercury rises quickly in the tube of the manometer, but as quickly falls as the temperature of the produced gas is reduced, and gains, after an interval of four or five minutes, a stationary position, which it retains for several hours with scarcely perceptible change. The temperature of the disengaged gas is then similar to that of the surrounding atmosphere. The manometrical height, as observed, multiplied by 100, gives the pressure. The following gives the elements of one of the determinations of experiments on powder used for charging cannon. The pressure of gas produced by 3, 4, or 5 grammes respectively at 27 deg. Cent., gave a height of 64.0, 86.5, and 10.6 millimetres of mercury. Reducing these results for 1 gramme, the respective heights of the mercurial column will be 21.3, 21.6, and 21.2 millimetres, giving a mean of 21.4 millimetres, with a range of 1 per cent.

The capacity of the eprouvette being 0.102 decimetre cube, the volume at 0 deg., and the pressure at 0.760 metre of mercury (30 in. English) of the gas produced by 1 gramme of powder, is arrived at by the formula:

$$\text{Vol.} = 0.102 \frac{214 \times 273}{76 \times (273 + 27)} = 0.271 \text{ cub. dec.}$$

The results obtained by experimenting on different kinds of powder, taking into account the amount of heat produced by the explosion, afford the following table:

Kind of Powder Used.	Calories developed.	Permanent volume in litres of gas produced by 1 kilogramme reduced to 0 deg. Cent., and 30 in. of mercury.	Pressure in atmospheres.	Maximum effective work in ton-metres.
1.	2.	3.	4.	5.
Fine sporting	807 8	4654	3989	373
Common powder ..	752.9	4360	4168	349
Gunpowder called BB	730 8	4231	4339	339
Commercial.........	694 2	4042	4160	324
Ordinary mining. ..	570.2	3372	3792	270

The results given in column 2 were obtained by the calorimeter, and represent the heat disengaged by the products of combustion of 1 kilog. or 2.2 lb. avordupois, English, of powder passing from the temperature of combustion to that of the external atmosphere. Taking into account the coefficient of the specific heat as the volume of gas produced by the combustion of the powder, it is possible to deduce the temperatures of combustion. According to this calculation they vary from 3,300 to 4,700 deg. Cent.; but considerable uncertainty attends such results, owing to the inexactitude which the various circumstances introduce into the experiments.

The pressures given in the fourth column are calculated by an application of the laws of Mariotte and Gay Lussac to the volume and temperature of the gaseous results of combustion. But as these hypotheses require modification, the results in this column must be considered as relative rather than exact. In column 5 the amount of work, expressed in ton-metres, afforded by the liberated gases, is given, this amount being the mechanical equivalent of the heat liberated.

MM. Roux and Sarran have carried on experiments with the same apparatus on other explosive compounds; but in these series of trials there were circumstances that vitiated the results—as, for example, the length of time before the final condition of the experiment occurs. The following table gives some particulars of the experiments:

Explosive Tested.	Calories disengaged by 1 kilogramme.	Weight of gas per kilogramme.	Reduced volume of as per kilog.
Gun-cotton	1056	0 853	720
Dynamite with 75 per cent. of nitro-glycerine	1290	0.600	455
Picrate of potash......	787	0.740	576
Mixture of 50 per cent. of picrate of potash and nitre..........	916	0 485	334
Mixture of equal weights of picrate and chlorate of potash..	1180	0.466	329

The results of these experiments are of great interest both for artillery and industrial purposes, especially in regard to mining operations. They are equally interesting as a branch of philosophical research which may give rise to further applications of great practical value.

FIRE-PROOF FLOORING AND FIRE-PROOF CONSTRUCTION.*

By LEWIS HORNBLOWER.*

From "The Building News."

The question of fire-proof flooring and fire-proof construction generally has for a long time occupied my attention, and was brought more forcibly to my mind by the gigantic fires that have occurred, not only in America, but in our own country. The loss of life, to say nothing of the loss of property, has been enormous, and the insurance offices have suffered considerably. I find, from a return made to the Board of Trade for the year 1871, that the losses of thirty-five insurance companies amounted in that year alone to the enormous sum of £2,197,004 14s. 3d., and this fearful loss has occurred notwithstanding all the advantages of the so-called fire-proof construction at present in practical use.

All descriptions of supposed fire-proof construction hitherto invented have miserably failed; iron girders and iron columns supporting brick vaulting have alike proved ineffective, and when subjected to great heat have collapsed. Professor Lewis, F. S. A. in a paper read before the General Conference of Architects, in 1871, states:—"The real difficulties of fire-proof construction begin where there is a large mass of combustible materials, as in warehouses and similar structures. In these the heat developed is something which an ordinary observer would scarcely credit. I exhibit some specimens of brass and iron nearly in a melted state, showing that the temperature which they had failed to withstand must have been some 2000 deg. Fahr.; the whole place, in fact, must have been a glowing furnace." The only structures that have successfully resisted the most intense fires, and remained firm and rigid during their continuance, have been floors of brick, stone, or tile carried on brick vaulting, supported on brick piers. This method of construction has great disadvantages, from the great amount of space occupied by the brick piers. The desideratum to be aimed at is the construction of a perfectly fire-proof floor capable of covering a large area unsupported by columns and girders of iron, which, at the same time, must possess carrying power to sustain heavy loads of merchandise, and also admit of carrying fire-proof division walls for separating the rooms on the upper stories of large public buildings, as, for instance, hotels, hospitals, private houses, etc.

My attention was more particularly drawn to this question at the Congress of Architects of Great Britain and Ireland, called together by the President and Fellows of the Royal Institute of British Architects, in May, 1871. I took considerable interest in the discussion that ensued, and determined, if possible, to invent a flooring that would be fire-proof. After many experiments I at last hit upon a flooring that combines all the qualities requisite to insure perfect security from fire, as well as enormous carrying power.

It was admitted by Mr. Aitchison, the architect for the S. Katharine's Dock Company, who had constructed a large number of warehouses for that Company, that iron columns supporting iron girders are not fire-proof, and that in cases where large fires had occurred, the girders and columns either melted from the intense heat, or cracked and collapsed the moment cold water from the fire-engines played upon them. Mr. Robert W. Edis, F. S. A., in a paper read before the General Conference of Architects, held in London, May, 1872, in "Notes on the Late Fires in Paris, May, 1871," states, with reference to the so-called fire-proof construction in use in that city:—"That the utter uselessness of stone construction to resist the action of fire is no new story; but those who were at all incredulous as to the reason or truth of this will, I imagine, be convinced by the entire failure throughout of the so-called fire-proof construction in all the fires in Paris." "Of wrought and cast iron as used in floors and roofs, the same remarks will apply as to their fire-proof capacity; both failed lamentably; and although the iron work did not of itself add fuel to the flames, as a general rule, it did much more damage by breaking and snapping, twisting and turning, than any wood construction could possibly have done. It was extraordinary to notice the eccentric forms into which the wrought-iron roofs—notice especially the roof over the Salle des Pas Perdus in the Palais de Justice—had been twisted; wrought-iron gir-

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* A paper read before the Liverpool Architectural Society.

ders of immense size were turned about by the flames like ribbon, and must in many cases have been heated to almost fusing point."

Captain Shaw, the energetic and intelligent Chief of the London Fire Brigade, stated at the Conference that his men absolutely dreaded trusting themselves on floors supported by iron columns and girders; that they have no confidence in stone staircases tailed into the side walls; but would have greater confidence in staircases of timber plastered on the underside, or in wooden floors supported on girders of timber, which, although subject to the action of fire, yet, at all events, gave the fireman some slight warning before succumbing to the devouring element. Seeing, from the mass of evidence produced, that iron and stone constructions are not fire-proof, and not to be depended upon, I directed my attention to a combination of fire-clay tiles and Portland cement concrete. It was necessary in this combination to use some small portion of iron as a tie, but I have used as little of this material as possible, and have placed it in such a position that no fire can touch it, or if it did, the effect would be harmless.

The object and scope of the invention is to provide walls, partitions, floors, and roofs of buildings at once light, cheap, durable, thoroughly fire-proof and convenient for ventilating the rooms or spaces they enclose. For these purposes I employ the materials hereafter named, in combination, for walls, partitions, floors, and roofs: iron or steel, hollow earthenware and cement concrete; and for partitions, under a modification—iron or steel, metal wire, earthenware pipes, and cement concrete.

Walls, partitions, floors, and roofs are constructed of sheet iron or steel, preferably so formed as to represent one-half of an octagonal honeycomb cell in transverse section, reversed and placed as flitches parallel to each other, with a space of 6 in. between the flitches. In this space are placed pipes of hollow earthenware, with the sides splaying outwards at the base to form a skewback. These pipes are in 2 ft. lengths, and the iron flitches are bolted to and through the earthenware pipes, thus forming a composite girder. These girders are placed 2 ft. from centre to centre at the proposed ceiling height, having $4\frac{1}{2}$-in. wall-hold at each end. A rough staging is required by way of support on which to lay the floors; between each skewback an earthenware hollow pipe—with oval-shaped head and flat soffit, with a dovetailed channel or indentation running longitudinally to receive plaster of ceiling—is placed, with sufficient room left between the composite girders to receive the charge of cement concrete. This is filled in from the upper side and well consolidated. The upper surface of floor is truly levelled and grouted with pure cement grout, and brought to a fair and smooth surface, if intended to form a finished floor; but if tiles, marble, flooring boards, or parquetry, are proposed to be used for finishing flooring, the concrete is simply levelled and left rough to receive the battens to which the boarded floors are nailed.

Holes are left in the soffits of the hollow pipes, where requisite, for ventilating the rooms below, and the pipes so utilized are connected with flues in the walls adjoining; or if it is desired, in these days of dear coal, to economize fuel, hot air may be conveyed, by means of these hollow tubes, from any central and convenient point in the basement, where a heating apparatus may be located, to any room throughout the building thus constructed.

In walls and partitions the iron and steel lengths are placed in a vertical, in floors in a horizontal, and in roofs in an angular position.

Partitions are constructed of half-octagonal honeycomb iron or steel cells, with metal wire stretched across, instead of laths, to receive the cement concrete or plaster, such wire serving to tie the iron and steel lengths, and at the same time to hold and strengthen the cement concrete or plaster. It will be obvious that bricks, flooring boards, tiles, marble, or other material or desired surfaces, may be attached to parts constructed in accordance with my invention, whether for floors, walls, ceilings, or roofs. I am satisfied that this is the only really fire-proof construction now before the public, and by far the cheapest.

In consequence of the extraordinary advance in the price of iron, I have been compelled, in order to keep down the cost of the floor, to economize in the use of wrought iron in its construction. I can now construct a floor without the octagonal iron flitches, simply by forming the composite girders separately, before fixing, by running a $\frac{5}{8}$ or larger diameter wrought-iron rod or bar, with nuts, head, and screws, through the centre of the hollow tiles, and charging the interior with fine cement concrete, gauged 4 to 1, and screwing the whole together, thus making a continuous beam and skewbacks to receive the hollow oval earthenware centres, which, in fact, throw the whole construction into a series of small arches, supported on composite girders, bound into a homogeneous mass by the cement concrete.

This mode of construction has many advantages for cottages either built separately (self-contained) or in accordance with the Scotch plan, where a number of dwellings are collected in flats, having access from a general staircase. It is cleanly, harbors no vermin, commands a ready means of ventilation—so necessary to the health and comfort of all, and so often unattainable by the poor—and would not entail constant repairing.

This construction would be of immense importance if used in the erection of hospitals, dispensaries, barracks, cotton manufactories, breweries, railway stations, warehouses, drying sheds, malt rooms, etc. It would be very valuable if used in the construction of floors over lock-up shops—so common in London, and in which, unhappily, so many fires have occurred, caused, I am informed by the police, in too many cases by fraudulent tradesmen who purposely set fire to their shops to rob the insurance companies, without any consideration for the unfortunate families that may be living above them. One great commendation is that it is cheap, and can be constructed by any laborer of ordinary intelligence.

Great care must be taken in thoroughly incorporating and amalgamating the materials forming the concrete together—old bricks, broken small enough to pass through an inch mesh, well-washed gravel and sand. Furnace slag, broken as before described, makes an excellent material to mix with the Portland cement to form the concrete. The proportions should be accurately measured; six, and (if the ballast is sharp and good) sometimes seven, of the materials above mentioned to one of the best double-tested Portland cement, carefully turned over twice while in a dry state, and well mixed. Too much water is fatal to the setting qualities of the concrete, because, when applied too copiously, it only washes away the cement from the mass; just sufficient water should be used to temper the whole, and the best mode of application is by a rose waterpot. The concrete should not be made in greater quantities than can be readily carried to the floors and used before it commences to set. In forming the floors this fact must be strongly borne in mind. The floor must not be constructed in layers, but the full thickness must be put in in one body; therefore no more should be attempted at once than can be satisfactorily completed the same day. When the floor has set for a fortnight the platform may be struck, but as the material gains strength daily until crystallization is complete, the floors should not be too heavily taxed at first.

The partitions, I am satisfied, would be very valuable if used instead of the stiled partitions, so generally used now to divide the rooms on upper floors—in fact, nearly all the internal divisions of London houses are simply constructions of timber. The weight of the partitions could be suspended by tension rods from the floors above, thus dividing the weight throughout the structure.

For cottages and smaller house partitions of 4 in. and even 3 in. thick would be ample. I embed the metal uprights in concrete, passing the rods through the pipes, as before described.

Now as to the carrying power of these floors. By practical experiment I have tested them in this particular. One specimen had a bearing of 7 ft. 6 in. between supports, with 3-in. wall hold at each end (this was tested simply as a beam of that breadth, not as a floor, which would have had the additional counteracting force of equilibrium to have aided it), and 14 ft. long. After giving it 18 days to set, the supports were removed, and it was loaded with 31 tons of dead weight, or 3½ tons to the yard superficial. Another specimen had a bearing of 15 ft. 6 in. between supports, with 3 in. wall hold at each end. After allowing it twenty-one days to set, it was loaded with 6 tons of dead weight in the centre, equal to a load equally distributed of 1 ton per superficial yard.

It has been very clearly shown by the experiments of Mr. John Grant, C. E., that Portland cement concrete does not attain its full tensile strength for years, the material gaining at the end of one year over 4 times the strength it possessed one month after construction; consequently, the bearing power of the latter specimen would be after one year about 48 tons distributed over the entire surface, or upwards of 4 tons to the superficial yard.

In addition to the flooring, I have invented a very simple method of rendering iron columns and girders already erected in buildings perfectly fire-proof, by means of a ring of fire-clay tubes attached to the periphery of the columns and soffits and sides of the girders, securely bound together and attached to the iron by Portland cement concrete, which allows of a free current of air between the iron and external facing of concrete. This casing adds only 2 in. to the thickness of the ring of the metal column.

I have refrained from bringing this matter before the public until I had proved its capabilities. I have had an opportunity of testing this practically and thoroughly in numerous buildings lately erected by me on this principle, in Cumberland, for the Directors of the Hodbarrow Mining Company. The spans I have covered have been 14 ft., but I can readily, and should not hesitate to carry a floor over a span of 22 or 24 ft., without any other support than that derived from the walls themselves, by increasing the depth of the composite girders.

These houses, 58 in number, in which I am introducing my patent flooring, are to be seen at Haverigg, in Cumberland. The material that is used for floors and roofs is simply sea-beach shingle combined with Portland cement. In the construction of the walls I have used the proportion of 8 of shingle to 1 of cement, and for the floors 6 to 1 of the same materials respectively, but am satisfied that in the larger proportion of 8 to 1 it would be equally satisfactory.

Concrete walls (and I speak from actual experience) of 9 in. in thickness, will bear as much as any 14 in. walls built of brick. It is superior in many respects; it is impervious to water, and the walls can be built by any ordinary laborer, under proper supervision.

With respect to the floor, it has greater carrying power than any flooring in existence, while the whole of the intermediate hollow space can be utilized.

The weight of the floor is 6 cwt. to the yard superficial, but this may be made less by reducing the depth of concrete on the floor. This invention is as useful for roofs as floors, it being only necessary to give a slight shedding towards the gutters. A good deal, however, depends upon the genuineness of the cement used; it must be equal in quality and well tested as to strength. In the floors that I have constructed I have used the very best Portland cement. I also tried some cement made at Bebington, in Cheshire. I had these cements tested in bars 2 ft. long by 2 in. square; weights were applied in the centre; each bar had a bearing of $\frac{3}{4}$ in. at each end after being made a fortnight. The Bebington cement broke with 97 lbs. weight, while the London cement only stood 49 lbs. I am informed that the component parts of the Liverpool cement are Welsh hydraulic lime and the clay silt of the Mersey; the London cement, chalk lime and the clay silt of the Medway. Of course they both undergo similar manipulation in the manufacture.

I think I may safely lay claim to the following advantages embraced in my invention:

1st. Great cheapness.

2d. Large carrying power.

3d. Less iron (and that carefully protected) being used in the construction, and the other materials used being perfectly uninflammable, its fire-proof qualities must necessarily be superior to those of any other flooring.

4th. In ordinary fire-proof floorings columns and girders of iron have to be used, placed at intervals varying from 8 ft. to 12 ft. apart, and these are totally unprotected from the action of fire. In this flooring, even for heavy warehouses, girders would be required 15 ft. or 16 ft. apart, and columns 20 ft. distance, and these are carefully encased with fire-proof material; thus, not only saving a large amount of expense in girders and columns, but giving the floors, even in the hottest fires, by calculation, at least six hours' grace (as compared with ordinary uncased columns and girders) before the columns would become red-hot; then, when water is played upon them, the casing would protect the columns and girders from the unerring action of the contact of the two elements, and enable them to cool down gradually.

5th. No ceiling joists or laths are required, the soffits of the fire-clay tubes being grooved and dovetailed to form key for plaster.

6th. The excellent opportunity given, where the floor is used, of conveying hot air to, or foul air from, the various apartments in which it is laid by means of the hollow fire-clay tubes; and this is of greater importance to the houskeeper since the great advance in the price of fuel, for here a great economy can be effected.

7th. In this construction I can observe no perceptible lateral thrust—the strain is all vertical.

8th. No harbor for vermin.

9th. No counterceiling required.

10th. The boarded floors need not be laid until all the plastering is finished.

Before going into the question of fire-proof flooring I thought it desirable to examine what had already been done in this particular. I therefore went carefully over the lists of patents, and derived no little amusement in the search. I thoroughly examined 317 separate patents. Many of these have secured provisional protection only; some refer to rendering buildings certainly water-proof, and partially fire-resisting only. During the last 240 years the subject of fire-proof construction has occupied the attention of our profession.

The earliest patent was granted to one Deekins Bull, 33 years before the great fire in London, viz., in 1633. It was granted by His Majesty Charles I., by the Grace of God King of England, Scotland, France, and Ireland.

TERRA-COTTA MANUFACTURE.*

From "The Architect."

Terra-cotta is, at the present day, prosecuted with greater enterprise than hitherto; great authorities speak highly in its favor, even where stone is plentiful; but where there is a scarcity of the latter, buildings in terra-cotta are more frequently adopted, and it is not uncommon that decayed stones in ancient buildings are replaced by this imperishable material. To estimate the shrinkage which any design will undergo from being formed in a plastic state to its being turned out thoroughly burned, is one of the great difficulties attending this department, and when great exactness is required, burnt clay, after being reduced to a fine powder, is mixed in a certain proportion with the raw clay to diminish the shrinkage to the utmost. Many compositions are used in the production of it; for instance, in various parts of England the natural clays are mixed with varied proportions of kaolin or china clay, Cornish stone, ground flint, etc., to make up a durable substance, and this composition is held to produce very fine work.

A few years ago I executed several contracts in terra-cotta for the Science and Art Department, South Kensington, for the museum there, consisting of balustrading, friezes, cornices, and other ornamental work, from the fire clay which I work at Lochhead, near Dunfermline, without mixture. About that time a paper, bearing on the qualities of the various compositions from which terra-cotta is manufactured, was discussed, which resulted in the weight of argument being rather in favor of the clays from the coal measures.

Terra-cottas are made in various colors, so that, when required for the replacing of decayed stones, the tints of the two may be exactly similar. The color is frequently merely washed on the surface, but in these cases the slightest chip or abrasion reveals a different shade, which is most objectionable, and it is, therefore, necessary that the color penetrate the whole substance. To effect this the coloring ingredient is added when the clay is in a dry state and properly mixed; it then goes through the batching pans, where water is applied to render it plastic.

The numerous designs in plain and ornamental chimney cans, so as to be in conformity with the style of the various buildings erected, form themselves a very extensive stock. Other architectural work, such as balustrading, columns, capitals, cornices, etc., and apart from the more useful productions, are the highly ornamental, such as fountains, vases, garden ornaments, and decorations, all of which swell the list of manufactures from the fire clay, causing them to form a very important outlet for labor, in which no small proportion of skilled labor is required.

A class of work to which the highest skilled labor is applied is in the production of statuary, and from the variety of processes through which it has to pass, it will be inferred that very great expense attends

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* From a Paper read before the Edinburgh and Leith Engineers' Society, by Mr. William Wilson.

it. The first and most important part is to select an artist of undoubted skill, thoroughly acquainted with the plastic substance in which his design is to be cast, who completes the model; plaster of paris is then made up to the consistency of cream, and poured uniformly over the whole surface to such a thickness as to give it a proper substance, and in this are placed small iron rods, which act as ties and give strength to the mould; the plaster of paris now stands sufficiently long till it sets, and speedily attaining a firmness, it is inverted and the subject taken from it. The artist then examines the whole very carefully, touching up with a small tool any imperfection, after which it is put on the stove for a day or so to be properly hardened before the mould can be said to be completed. These moulds in various subjects are very intricate, and consist of numerous parts, all of which are fitted together in such a way that each of the parts can be independently disunited.

The clay for this department is specially prepared, and partakes to a great extent of the same process as for China ware in potteries. For this preparation a "slip plate" is used (which is simply a fire clay trough of considerable length), under which runs a flue, heated by means of a furnace at one end. The ground clay being soaked in water is put through a very fine lawn sieve into this "slip plate," and is heated by the furnace up to boiling temperature, and continued until as much water is evaporated as will render the clay of a consistency fit for use. It is then taken out and thoroughly beaten and kneaded by hand to drive out the air, and this being completed it is taken to the moulder. This very fine clay is now firmly pressed by hand into all parts of the mould, and these parts are all fixed together and properly jointed. To the clay has thus been imparted an exact outline of the design, which remains in the mould two days or so, until a degree of stiffness has been acquired, after which the various pieces of the mould are carefully removed. The superfluous clay at the joinings is now pared off with a knife, and the whole figure undergoes a process of very fine finishing, which is a special branch requiring very experienced and artistic workmen, and, in order to prevent sinking or twisting in those figures and designs that have the top part heavier than the lower, it is frequently necessary to provide supports at this stage of the manufacture. Statues, fountains, and other similar productions are taken direct to the kiln and fired, retaining unimpaired the last touches of the artist.

The kilns in which the finer class of terra-cotta is burned are termed "muffled" kilns, from their being constructed with a casing (a brick thick), inside of which all the goods are placed, thus being thoroughly protected from the flame. A space or flue, about 4½ in. wide, is left between this casing and the outside wall. The extra expense in heating up this description of kiln is very considerable, but there is not the risk of beautifully finished figures or designs turning out after being burned with scorched surfaces, as occasionally occurs in the open kilns; and while the casing only allows the heat to be brought up very gently, the highest degree of white heat necessary can be raised, so that there is not the slightest danger of giving way under exposure to the most severe weather.

ON THE LOAD-DRAUGHT OF STEAMERS.*

By W. RUNDELL, Esq.

From "The Nautical Magazine."

Of late public attention has been so powerfully directed to the subject of a load line in connection with the safety of our seamen, that a cry has been raised (I believe a most mistaken and injurious cry) for the interference of Government with the loading of ships, and fixing a deep load line, laden beyond which no vessel may be allowed to go to sea. This, in my opinion, is not a proper subject for discussion by the Institution of Naval Architects. The data for it lie outside the special experience of the naval architect, and must be gathered from experts. The immediate subject of my paper, on the contrary, appears to me especially well suited to your consideration; and I respectfully submit my suggestions to your criticism, in the hope that, if approved by you, the Government may be induced to speedily adopt them. With the strongest conviction that the load-draught of any particular ship should be left to the

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* A paper read before the Institution of Naval Architects.

persons immediately concerned, and that none of these parties should be specially protected by the State in making his bargain or engagement, I believe that the Board of Trade might, with propriety, be called upon to assume the responsibility of making certain marks on a ship's side, to represent certain facts in precisely the same way in which the Board now superintends the correct marking of the scale of feet on a ship's bow and stern, the cutting of the official number on the beam at the main hatch, or the insertion of the ship's cubical capacity on her certificate of registry.

My first proposition is, that a portion of each side of every steamer shall be marked with a scale of capacity; that this scale shall be obtained in a certain way, and marked in a certain position. My scale is one of proportion only, and it is proposed that it shall be painted, or otherwise permanently marked on the upper side, amidships, of all steamers. The marks would be 18 in. long, and placed 1 ft. apart. On each line would be figures 6 in. in height, indicating the percentage of the internal capacity of the vessel, which lies above it. The scale would be placed on each side of the vessel, in a vertical line 1 ft. abaft the middle vessel, "between the perpendiculars."

It would not be a long or tedious operation to measure the upper part of each ship specially for the purpose; but this is scarcely required, as the length, breadth, and details of tonnage are believed to be quite sufficient for the purpose. In my last paper the cubic contents in register tons of each horizontal slice, a foot in thickness, of that part of a loaded ship which is above water, was taken as equal to the registered length multiplied by the registered breadth, multiplied by .8 and divided by 100. If the number of registered tons under tonnage-deck be divided by the number just obtained, the quotient will represent the number of feet of free-side which will lie above the 30 per cent. plane.

Having thus obtained the distance below the tonnage-deck of the 30 per cent. plane, the next step is to ascertain the percentage of each foot as measured from the datum-mark opposite the tonnage-deck. From a displacement scale, representing the mean of a number of vessels, a linear percentage scale was prepared, in which the intervals gradually increased as the vessel's capacity at the part represented on the scale decreased, and this was carried on by 1 per cent. at a time until it was extended to 40 per cent., as the utmost limit likely to be wanted. The other side of the scale is divided, so that the distance from 0 to 30 shall represent 1,000 equal parts. It is to be used in the foregoing manner.

Divide 1,000 by the number of feet and parts representing the free-side for 30 per cent. of internal capacity: the quotient will indicate on the scale the percentage at the 1-foot mark, twice the quotient will indicate the percentage at the 2-foot mark, three times at the 3-foot mark, etc., etc., up to 40 per cent., if wanted.

For example, let the vessel be 1,000 tons under tonnage-deck; length, 200 ft.; breadth, 30 ft.; $\frac{1{,}000 \times 3}{\frac{200 \times 30 \times .8}{100}} = \frac{300}{48} =$ $6\frac{1}{4}$ ft. for free-side to represent 30 per cent. of capacity.

Next divide 1,000 parts on the scale by $6\frac{1}{4}$, and we obtain 160 as the scale number for the percentage which reads off 5.6 per cent., and the multiples of 160 for the successive marks 1 ft. apart will give the following percentages:—11.0, 16.0, 20.6, 24.8, 20.9, 33.0, 36.8, 40.2.

Mr. Rundell then explains the allowances he proposes for sheer and for erections above the tonnage-deck, one-sixth of the mean sheer, and one-fourth of the height of the awning-deck, and one-fifth the mean height of other erections. By mean height he means their cubic capacity divided by the horizontal area of the vessel above the water-line.

The adoption of the above or any other reasonable allowance would not bind any one to a fixed load-line, and would reduce individual differences of opinion to a little space on one side or other of the customary percentage mark. Experience would soon show which percentage mark gave in practice the most satisfactory results.

The use of marks amidships, showing percentages of internal capacity instead of the actual tonnage cut off above, has several advantages. 1. It does not require a knowledge of the details of the registered tonnage of the vessel before any idea can be formed of the proportion of the vessel's bulk which the figures indicate. With a scale showing tonnage, reference must be constantly had to the ship's register, while with a percentage scale the figures to be considered are those with which every one is familiar. 2. Such a percentage scale would tend to generalize our ideas as to safe load draught, and be of especial value in treating the draught of very long steamers, or vessels of other unusual proportions, by enabling us to compare them in similar terms. Lastly, if the Legislature should decide on fixing a deep load line beyond which no vessel should be loaded, it would enable them, instead of naming a rigid hard and fast line, to fix different percentage marks suited to the class, age, condition, and usual voyage of each vessel.

The paper was illustrated by diagrams, representing a portion of the midship section, and also 10 ft. in length of the top side of each of those vessels respectively, of 1,000, 2,000, and 3,000 tons under deck. These are respectively marked with the following figures to show the percentage of the internal capacity of each vessel which lies above the line on which the figures stand:

1. Steamer of 1000 Tons.	2. Steamer of 2000 Tons.	3. Steamer of 3000 Tons.
7.2	5.1	4.8
14.1	10.1	9.4
18.3	14.7	13.7
24.2	19.0	17.8
29.7	23·0	21.7
34.8	27.0	25.3
39.6	30.6	28.7
	34.2	32.2
	37.6	35.4
	40.8	38.6

STRENGTH OF BOILER SHELLS.*

From the "Nautical Magazine" and "Engineering."

1. The Board of Trade, while allowing their surveyors to choose their own forms of calculation, have all along recognized as the fundamental principle of their practice, the following opinion, expressed by Sir William Fairbairn, in 1854, viz: "Steam boilers of every description should be constructed of sufficient strength to resist 8 times the working pressure, and no boiler should be worked, under any circumstances whatever, unless provided with at least 2—I prefer 3—sufficiently capacious safety valves."

2. In 1868, each of the surveyors was called upon to send to the Board of Trade a report, giving in detail a statement of the rules they used in determining the working pressures to be allowed on the boilers that came under their survey, and their method of inspection. It appeared from these reports that although the arithmetical forms of calculation were not uniform, yet the results arrived at were, in every case, so nearly alike, and were also so near to the pressure required by the maxim laid down by Sir William Fairbairn, that the Board did not, in the case of any one of the reports, interfere with the method of calculation the surveyor had adopted.

3. The most of the surveyors gave as their practice, a rule that had been long well known amongst engineers as "Galloway's rule," and as both manufacturers and surveyors seemed to have the same rule, there did not appear to be any occasion for upsetting a practice that was working so well. In some of these reports, however, a matter was introduced as affecting in an important degree the practical value of "Galloway's rule," viz., the actual proportions of riveted seams. It is stated that manufacturers were departing from certain proportions for which alone Galloway's rule was applicable. As this divergence has since led to considerable misunderstanding between manufacturers and the Board's surveyors, it may be interesting to explain what has been the nature of this difference. To understand that, it will be necessary to go to the origination of the rule.

4. The rule in question was formed by the late chief surveyor, Mr. Galloway, as an embodiment, in a practical form, of the practice of the Board's surveyors in carrying out the principle above quoted from Sir William Fairbairn, that the actual factor of safety in all steam boilers should not be less than 8. The following is the rationale of the construction of Galloway's rule.

5. In the absence of tests witnessed by an officer of the Board of Trade, the strength of iron is assumed to be 48,000 lbs. per sq. in. in plates and rivets; this includes the effect of friction at the joints, and supposes the holes to be drilled, the

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* We are indebted to the "Nautical Magazine" for the above article, and for some additions to it, which were kindly forwarded to us in reply to our request for permission to reprint.

strain to be applied lengthways to the plate, and the rivets to be Lowmoor, or equal to that in quality. When the rivets are subjected to double shear, or where the strain is applied crossways to the plate, only 43,000 lbs. is allowed as the strength per square inch of the rivet, or of the plate respectively. The other details of strength standards will be given further on; the first of these statements is all that is necessary to explain Galloway's rule. In that rule the section of the shell is taken as the length of the boiler by the thickness of the plate; but practically, the length of section will be greater than the length of the boiler on account of the doubling of the plates at the circumferential seams. When the double riveting is zigzag, as it should always be in boiler shells, the section is increased about 7 per cent. by this extra material. To give effect to this, the 48,000 lbs. was increased about 7 per cent., or to 51,520 lbs., or 23 tons.

6. According to Fairbairn, the strength of properly proportioned double riveted joints is 70 per cent. of that of the solid plate, and as the shift of butts longitudinally in the shell plating should be at least one strake, the weakest section will be alternately a solid plate and a riveted seam, or

$$\frac{100 + 70}{2} = 85 \text{ per cent.}$$

as the average strength of the whole section as compared with the solid plate. To permit retaining the 70 per cent. as the description of the riveting instead of altering this percentage to 85, an equivalent reduction was made upon the factor of safety 8, by substituting for it a divisor, 6.5;

$$\frac{70 \times 8}{85} \text{ being nearly equal to } 6.5.$$

7. For single riveted seams the excess for laps is proportionately less, and the addition of strength by the shift of butts is proportionately more, and the resultant is approximately also the substitution of a divisor, 6.5, instead of the factor of safety, 8. As

$$\frac{23 \times 2240 \times .70}{6.5} = 5550,$$

and

$$\frac{23 \times 2240 \times .56}{6.5} = 4440.$$

"Galloway's rule" assumed the following form for boilers of the best construction and workmanship, the dimensions being taken in inches:

$$\frac{5550 \times \text{twice the thickness}}{\text{diameter of the boiler.}} = \left\{ \begin{array}{l} \text{Allowed pressure for} \\ \text{70 per cent. double} \\ \text{riveting.} \end{array} \right.$$

$$\frac{4440 \times \text{twice the thickness}}{\text{diameter of the boiler.}} = \left\{ \begin{array}{l} \text{Allowed pressure for} \\ \text{56 per cent. single} \\ \text{riveting.} \end{array} \right.$$

8. In this form "Galloway's rule" became well known, but, unfortunately, those outside the Board of Trade, in many cases, soon lost sight of its fundamental principle, viz., the actual factor of safety to be 8, and of the standard of riveting to which alone it applied, viz., 70 per cent. in the double riveted joint, and 56 per cent. in the single riveted joints. As with the spread of compound engines higher pressures became general, and the thickness of shell plates was increased, the 70 per cent standard was not adhered to by manufacturers, and in some cases the strength of double riveted joints was actually less than 56 per cent, which was the standard for single riveting in the construction of "Galloway's rule."

9. Manufacturers, in these cases, although they had departed so far from the principle of the rule in their proportions, nevertheless continued to calculate the pressures by "Galloway's 70 per cent. rule," and, of course, the pressures they expected were not allowed by the Board of Trade.

10. "Galloway's rule" is altered in the following way to suit different strengths of double riveted seams, the joints being properly crossed:

Rule,

$$\frac{(515 \times (70 + \text{percentage}) \times \text{thickness of plate}}{6.5 \times \text{diameter of boiler}} = \text{pressure.}$$

Or nearly

$$\frac{70 + \text{percentage}) \times 80 \times \text{thickness}}{\text{diameter}} = \text{pressure.}$$

For single riveted seams, substitute 56 or 70 in the above.

The "percentage" to be used in the above is the least of the two valves found by formula in paragraph 19.

11. Mr. Galloway's rule was made for boilers of the best workmanship, and for plates much thinner than those now common in high-pressure boilers. The increase in thickness has not only caused a departure from the 70 per cent. standard, but it has in many other respects lessened the strength per square inch of section of the shells of boilers; the bending of a plate in the rolls, after the end holes are in, is more

injurious to a thick plate than it would be to a thinner one; thick plates have less tensile strength per square inch of section than thinner plates have.

12. Board of Trade surveyors have always been influenced by such considerations in fixing the pressures to be allowed on boilers. In applying to ordinary marine boilers the reductions which, according to even the most liberal interpretation of a surveyor's duty, are seen to be necessary to maintain in its integrity the maxim laid down by Sir W. Fairbairn, the pressures allowed fall, in many cases, far below the pressure resulting from the current misapplication of the popular form of Galloway's rule, and the disappointment to manufacturers, and their complaints, laid at the door of the Board of Trade, should be recognized as due to themselves only, and should be taken upon their own shoulders.

13. Two courses of action are open to manufacturers, either to combat the opinion of Sir William Fairbairn and have it expunged from the standard code of engineering practice, or, on the other hand, to adopt such improved methods of construction or stronger materials as will justify a higher pressure in accordance with that opinion.

14. The responsibility upon the Board of Trade is a very serious one, but, at the same time, their duty is very clear. So long as the above statement of opinion stands uncontroverted, the travelling public have a right to demand from the Board of Trade the condition of safety therein defined. I, as a surveyor, may or may not consider such a margin of safety as in every case necessary, but it would never do for every surveyor to set about experimenting with the lives of the public to discover whether he or Sir William Fairbairn were the better authority on this point. It is clearly understood that this factor of safety is a matter of settled policy, not one for the exercise of individual opinion. But what surveyors cannot do, and what even the Board of Trade ought not to do, it is still open to the great engineering lights of the day to do. They may alter public opinion, they may refute the statement on which the Board's policy rests, and they might even succeed in getting Sir William to retract his statement and to side with those who are opposed to it, and then there is no doubt that the Board of Trade would not consider it their duty to force upon the public a higher degree of safety than the public themselves cared to possess.

15. In this paper my object has been to explain and to justify the action of surveyors in fixing pressures. Galloway's rule, although at the bottom substantially correct, was, in reality, only an empirical formula, and it is, perhaps, to be regretted that the more detailed, although less practical method originally adopted was ever departed from. According to that system the bursting pressure was calculated from the dimensions of the boiler taken in detail, and that pressure divided by 8, gave the working pressure.

16. In applying this principle in the case of boiler shells, the Board's surveyors do not reckon the ends of a circular boiler as adding anything to the strength of the weakest section, and they take into account the actual percentage of strength left in the riveted seams, as found by paragraph 19, and they allow for the extra section afforded by the laps of the plates, or by butt straps, and by the crossing of the plates; they make the proper deductions for openings in the shell, and they calculate the pressure to be allowed for the dimensions of the weakest section, not the mean of two opposite sections, but the weakest section at one side of the shell only.

17. In the absence of tests witnessed by an officer of the Board of Trade, the following are assumed to be the strengths of the materials:

	lb. per sq. in.
Plates, lengthways, drilled..........	48.000
" crossways "	43.000
" lengthways, punched........	40.000
" crossways "	36,000
Rivets, Lowmoor, single shear.......	48,000
" " double "	43,000
" common, single "	40,000
" " double "	36,000

18. The strength of the whole of the weakest section is taken piece by piece, and the sum divided by the half diameter of the shell is the bursting pressure.

19. The strength of the longitudinal riveted seams in percentage of the solid plate is calculated by the least of the two following percentages:

Plates.

$$\frac{(\text{Pitch—diameter of rivet}) \times 10 \times 10}{\text{pitch}} = \left\{\begin{array}{l}\text{Percentage of}\\ \text{plate at joint, as}\\ \text{compared with}\\ \text{the strength of}\\ \text{the solid plate.}\end{array}\right.$$

If the holes are *punched*, substitute 8⅓ for one of the *tens*. If the strain is applied crossways to the plates, substitute *nine* for one of the *tens*. If the plates are bent after the end holes are in, substitute 9 for one of the *tens*. The last two of these substitutions will never be both required for properly constructed circular boilers.

Rivets.

$$\frac{\text{Area of rivet} \times \text{No. of rows of rivets} \times 10 \times 10}{\text{pitch} \times \text{thickness of plate.}} =$$

per centage of strength of rivets, as compared with the strength of the solid plate.

When the rivets are subjected to double shear, the *number of rivet sections to be sheared* is to be substituted for the *number of rows of rivets*, and the number *nine* is to be substituted for one of the *tens* in the above.

When the rivets are only of common rivet iron, instead of being of Lowmoor, or similar iron, $8\frac{1}{3}$ is to be substituted for one of the *tens* in the above.

20. The weakest section may run through seams all along if the shift of butt be not sufficient, or it may run alternately through a seam and a solid plate; the latter is the line it usually takes. The strength of the shell is then nearly a mean between the strength of the seam and the strength of the solid plate, or with a 70 per cent. seam we get

$$\frac{100 + 70}{2} = 85 \text{ per cent.,}$$

and the extra for material in laps has to be added. The rule used for the minimum shift of butts is

$$\frac{110\text{—percentage of riveting}}{\text{percentage of riveting}} = \text{length of shift of butts}$$

expressed as a portion of the whole breadth of the plate.

Example.—If the percentage of strength of the seam be 70, we have

$$\frac{110 - 70}{70} = \frac{40}{70} = .57 \text{ of the breadth of the plate.}$$

The addition of 10 to the 100 is intended as an equivalent for the metal in the circumferential laps, and to give the quotient, so that it can be applied from centre of seam to centre of seam, instead of between seams.

This shift of butts makes the strength of the intercepted circumferential seam at one of the seams equal to the deficiency between the strength of one of the longitudinal seams and a solid plate of the same breadth. In boilers plated after the pattern of brick bond, as is the general custom, only every alternate longitudinal seam has to be supplemented by the strength in the shift, and consequently the strength of both of the intercepted portions is taken into account. In common plating, therefore, only half of the shift given by the above rule is required, and the rule is meant for the system of plating advocated in next paragraph. Strictly, the percentage of riveting used in the denominator should be that percentage which is due to the rivets, not that due to the plates, but using the least of the two, as in the above, will err, if at all, on the safe side.

21. If manufacturers desire higher pressures, here is an inexpensive way to secure greater strength: economize the shift of butts; instead of always making the shift equal to half the length of the plate make it equal to $\frac{1}{3}$ or $\frac{1}{4}$ of the length. If the length of the plate, from centre of seam to centre of seam, be equal to n times the length of shift of butts, and if the percentage of the strength of the seam be given, we have

$$\frac{100\,(n - 1) + \text{percentage}}{n} = \left\{\begin{array}{l}\text{percentage of strength of} \\ \text{shell as compared with} \\ \text{solid plate,}\end{array}\right.$$

besides the strength due to the extra material in the circumferential laps.

22. This system has never been adopted in any boiler submitted for survey, although its value in making up the longitudinal strength of a ship's hull is a fact well known to engineers. The boiler ends, never being calculated directly, may, in this way, be indirectly made available in adding to the strength elements of the boiler shell by observing that there is always a good shift left between the seams in the end and those in the extreme plates of the barrel of the shell.

23. In this journal for May and for June of last year there appeared articles on the strength of riveted seams, both by Board of Trade surveyors. The present article, also by a Board of Trade surveyor, agrees throughout with those articles, except in one item, that here the strength of boiler plate is taken as 48,000 instead of 47,000 lbs. The values given in the present paper are in extension of the principle followed out in Mr. Wymer's paper in the May number, which applied only to equal values for the strength of rivet and of plate.

24. If the plates of the shell are not of excessive width, say total width not more than 40 times their thickness, the above principles would be applicable and with riveting, whose proportionate strength was even only 60 per cent., the strength of the shell could be made nearly equal to solid plate. Example:—

$$\frac{110 - 60}{60} = .83.$$

The circumferential shift of butts would be .83 of the breadth of the plate, say plates 36 in. wide, the shift would be 36×.83= 30 in.

25. If the longitudinal shifts be made three strakes apart, that is on the fourth strake, the length of the plate, centre of

seam to centre of seam, will be $4 \times 30 = 10$ ft. The strength of shell would be

$$\frac{100\,(n-1) + \text{percentage}}{n} = \frac{360}{4} = 90 \text{ per cent.}$$

If the material in circumferential laps amounts to 7 per cent. extra, that is about $2\frac{1}{2}$ in. at each lap, the total strength of shell will be

$$90 \times 1.07 = 96 \text{ per cent. of the solid plate ;}$$

or, 107 might be used instead of 100 in the preceding formula; this would drop the 7 per cent. on the seam and allow for thinning the corners.

And if the strength of the plate be 48,000 lbs. per square inch, for the effect of punching has been already accounted for in the low percentage taken for the riveting, we get

$$48{,}000 \times .96 = 46{,}080 \text{ lbs. per sq. in. as the strength of the shell.}$$

The eight part of this is the working strain,

$$\frac{46{,}080}{8} = 5760,$$

or a little more than the working strain allowed per square inch according to the popular form of Galloway's rule for 70 per cent. joints and drilled holes. With the butts arranged as above, and the plates of sufficient length, if the strength of the seam were even as low as 45 per cent. the pressure to be allowed would still work out to be as high as that due to 5,500 lbs. per square inch of gross section. It is evident, therefore, that if a pressure be given less than that due to Galloway's supposed rule, manufacturers have only themselves to blame. The additional strength pointed out would be obtained at absolutely no extra cost.

26. The thick plates of marine boilers should always be double riveted, even although the required pressure may be arithmetically due to an arrangement of single-riveted seams.

27. The principle of the calculation herein set forth takes advantage of every known element of strength in the shell, and assigns to it its full value. It is not strictly accurate, because it is impossible to determine the actual conditions of strain in any composite structure ; but the system of averages, or the hypothesis of equal distribution of load, is the basis of all engineering estimates of strength. For the high-pressure boilers to which this paper is directed, the plates are generally narrower in comparison to their thickness than the thinner plates of single-riveted smaller boilers. In Fairbairn's writings on strength of boilers he gives as the strength of a single-riveted seam 56 per cent. of that of the solid plate. These plates have generally a breadth about equal to 100 times their thickness ; but Fairbairn states that such boilers, by reason of brick bond crossing of the joints, have their strength increased 20 per cent. In accordance with that, he gives the strength of single-riveted boiler shells as 20 per cent. in excess of the strength of the riveted joint, and he forms the constants for his rules not upon 56 per cent. but upon

$$56 \times 1.20 = 67.2,$$

or 67 per cent. of the strength of the joint.

If we increase the 70 per cent. due to double-riveted joints *per se* in the same proportion, we would have

$$70 \times 1.20 = 84,$$

or nearly equal to

$$\frac{100 + 70}{2} = 85 \text{ per cent.,}$$

as used in this paper. I am aware that this mode of increase by percentage is not engineeringly correct, but its argument is better understood by some readers than is the system of means I have worked upon.

28. To some minds it may appear that a considerable reduction ought to be made on the mean of the strengths of the elements of the weakest section. To all engineering structures the same objection applies; the gross load is divided over the gross section, and the "breaking load" is that which would produce destruction, on the hypothesis that every element of strength will be effective up to its calculated individual strength. To a greater or less extent such a condition never exists in practice, and if this paper had been directed exclusively to the strength of brick bond plating, a small reduction, certainly not amounting to sacrificing the strength due to the extra material in the circumferential laps, might have been proposed as an equivalent; but as my object has been the better disposition of the plates, so that the amount of riveted joint in the weakest section is always only a very small percentage of the total section, the proper reduction would be too small to have any importance.

MODERN LOCOMOTIVES.*

From "Iron."

The author commenced by stating that in the present day, with a view to lessen the capital expenditure on railways, engineers have been compelled to follow more closely the contour of the country both as regarded the vertical profile and the general direction of valleys and hills. The consequence had been severe gradients, often concurrent with curves of small radius. This fact, taken in conjunction with the circumstance that in the colonies and in less developed districts, high speeds and frequent communication were not necessary, had led to the employment of heavy engines for the purpose of gaining great tractive power, since load rather than speed was the desideratum. A like state of things existed in most parts of the Continent of Europe, where heavy and slow trains, both of passengers and goods, were the rule ; thus permitting the service to be carried on at a much lower rate per ton per mile than the rapid traffic of Great Britain rendered possible. Of late years the passenger traffic had so increased in the United Kingdom that even express trains were now worked, for the most part, with coupled engines, the additional points of contact with the rails being imperative in order to prevent slipping, and to afford greater facility in starting. Increase in the size of engines had everywhere been found to be a necessity, and while the outside frames of inside cylinder engines had been generally abandoned, the inside cylinder arrangement had been almost universally adopted, notwithstanding the disadvantage it presented of a cranked driving-axle.

The details of construction of different types of engines and their adaptation to the work required were then described. Attention was first directed to the Great Northern Railway express engine, in which outside cylinders had been resumed, perhaps as a necessary consequence of the adoption of a bogie frame with four wheels, instead of a pair of leading wheels, to insure greater freedom in passing round curves at high speeds. The cylinders were 18 inches in diameter, with a length of stroke of 28 inches —a size, it is believed, never before attempted for passenger engines in this country. The small ends of the connecting rods were furnished with solid bushes of gun-metal, and had run more than 50,000 miles without renewal. The inner and the outer fire-boxes were connected together by stays screwed into each of the plates without the intervention of iron girder bars. By this arrangement, which had been in use for some time in Belgium, the large amount of deposit usually existing upon girder-boxes was prevented, the facility for cleansing was much greater, and the liability of the tube-holes in the copper plate to become oval had been got rid of. The heating surface in this engine was—in the tubes, 1,043 sq. ft. and in the fire-box 122 sq. ft. The fire-grate had an area of 17.6 sq. ft. When the engine was in working order, the weights upon the driving and hind wheels and upon the bogie were 15, 8, and 15 tons respectively. The distance from the centre of the hind wheels to the centre of the bogie pin was 19 ft. 5 inches. This engine was capable of drawing a weight of 356 tons on a level at a speed of 45 miles an hour, with a working pressure of 140 lbs. to the sq. in. The consumption of coal, with trains averaging 16 carriages of 13 tons weight each, had been 27 lbs. per mile, including getting up steam and piloting. The cost of maintaining and renewing passenger engines on the Great Northern Railway was estimated to amount to 2½d. per mile.

The next example selected was the London and North Western Railway fast passenger engine. In this case the cylinders were inside, between the frames—in the smoke-box, in fact,—and had a diameter of 17 inches, with a length of stroke of 24 inches. The boiler was fed by two Giffard injectors, placed vertically behind the fire-box. The admission of water to the injector was regulated by a screw with a wheel handle. The water ascended, and passed through a clack box (which could be closed at pleasure) into the boiler along an internal pipe, carried forward two-thirds of the length of the barrel of the boiler; all external pipes running forward outside the boiler were thus done away with, and greater simplicity and freedom from accidents were secured. The heating surface in this engine was

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*A paper read before the Institution of Civil Engineers (London) by John Robinson, C. E.

1,013 sq. ft. in the tubes, and 89 sq. ft. in the fire-box. The area of the fire-grate was 15 sq. ft. The distribution of the weight on the wheels, when the engine was in working order, was 9 tons 9 cwt., 11 tons and 8 tons 15 cwt. on the leading, driving, and trailing axles respectively. The total wheel base was 15 ft. 8 in. This engine would draw a load of 293 tons on a level at a speed of 45 miles an hour, with a working pressure of 120 lbs. to the sq. in. The consumption of coal per mile was 20.3 lbs. with trains averaging 10 carriages; and the cost of repairs, over a period of six years and a half, had been 0.52d. per mile run.

The six-wheeled coupled goods engine, made for the Great Southern and Western Railway of Scotland, and consequently suited for a gauge of 5 ft. 3 in., was next described. In this case the cylinders were 17 in. in diameter, with a length of stroke of 24 in. The tires of the wheels and axles were of cast steel. The coupling rod ends were furnished with cast iron bushes, lined with white metal. The small ends of the connecting rods had wrought iron steps, case-hardened. Sand-boxes were fixed in the smoke-box; and a steam brake was applied. The heating surface in the tubes was 846, and in the fire-box 93 sq. ft. The fire grate had an area of 17½ sq. ft. The weights upon the leading, driving, and trailing-wheels were 10 tons 17 cwt., 11 tons 7 cwt., and 8 tons 15 cwt. respectively. The total wheel base was 15 ft. 6 in. This engine would draw a load of 607 tons on a level, at a speed of 25 miles an hour, with a working pressure of 140 lbs. to the sq. in. The average consumption of coal was 35 lbs. per mile with a load of 55 wagons. The cost of repairs had been 0.63d. per mile.

The next engine referred to had been specially designed for the heavy goods traffic on the Bombay, Baroda, and Central India Railway, where the gauge (5 ft. 6 in.) had afforded great facilities for the construction of a powerful machine on a reasonable length of wheel base. The cylinders were 18 in. in diameter, with a stroke of 24 in. The escape of smoke when the engine was standing still was prevented by the application of Mr. D. K. Clark's apparatus for the introduction of air above the surface of the fire. There were 1,278 sq. ft. of heating surface in the tubes, and 99 sq. ft. in the fire-box. The area of the fire-grate was 25½ sq. ft. This engine would draw a load of 694 tons on a level, at a speed of 25 miles an hour, with a working pressure of 140 lbs. The consumption of coal was 59¼ lbs. per mile for an average load of 490 tons. The cost of repairs had been 3-22d. per mile. A peculiar feature of this engine was the position of the hind axle under the fire-box, permitted by the shallowness of the end of the latter. This arrangement answered the double purpose of allowing a comparatively short-wheel base and an equable distribution of the weight of the engine upon the wheels, 11 tons, 11 tons 16 cwt., and 11 tons 16 cwt. being carried on the leading, the trailing, and the driving wheels respectively.

The locomotive next described was of the class usually called "tank engine," and was constructed for the conveyance of mineral or heavy goods traffic over a portion of the Furness railways, having gradients of 1 in 100, 1 in 80, etc., for eleven miles. This engine was designed to obtain as much power as was possible on six wheels. The frames had been put inside the wheels to allow convenient access to the motive parts; the cylinders being placed inside to secure great structural stability. The cylinders were 18 in. diameter, with a stroke of 24 in. Tanks, to contain 1,000 gallons of water, were arranged along each side of the smoke-box, the boiler, and the fire-box, above the level of the frame, so as to distribute equal weights upon the wheels, which, when the engine was in working order and the tanks were full, were 13 tons 6 cwt., 14 tons 11 cwt., and 13 tons 8 cwt. on the leading, driving, and trailing wheels respectively. The total wheel base was 15 ft., the heating furnace in the tubes was 1,048, and in the fire box 96 sq. ft.; the area of the fire-grate was 15 sq. ft. This engine would draw a weight of 872 tons on a level at a speed of 20 miles an hour, and a weight of 367 tons up the incline of 1 in 80 at a speed of 11¾ miles an hour, with a working pressure of 145 lbs. to the sq. in. The consumption of fuel with this latter load had been 40.16 lbs. per mile.

For engines with rigid frames, a simple and convenient arrangement had recently been applied in the shape of a sliding top to the leading, and sometimes to the trail-axle-boxes. This cap had a double incline in the transverse direction of the engine. The axle-box had also similar corresponding inclines, so that when passing round a curve the leading wheels were free to move sideways without at once carrying the engine with them. This plan had been largely adopted on the Midland Railway.

Details were then furnished of the Fairlie system of locomotives, designed with the object of giving extreme freedom of movement to the engine and wheels, while securing sufficient stability to the boilers and their adjuncts. It had likewise been sought to utilize the whole weight of the fuel and water for the purposes of tractive adhesion. In conclusion, the author alluded to the great advantages which had accrued to the users of locomotive engines by the adoption of steel instead of iron for many parts, especially for tires and axles, whether the latter were cranked or straight.

SAFETY OF NAVIGATION.

From "The Nautical Gazette."

The American Association for the Advancement of Science enjoyed a most interesting session at Portland, Me. From one of the papers presented we make the following extracts:

Paper No. 37 of the catalogue was "The Coefficient of Safety in Navigation; an attempt to ascertain within what limits a ship can be located at sea by astronomical observation." The problem to be solved is to obtain average number of miles error which may be fairly charged upon an observation at sea under ordinary circumstances. The coefficient of safety is the quantity by which this number must be multiplied to secure absolute safety. I define it to be the ratio between the average error and the range of error. To show that this is not idle inquiry, the ratio of the increase of the number of vessels was compared with that of the number of wrecks, and the results certainly go far to confirm the practical value of the theory. The problem of wrecks was discussed under four heads:

1. Wrecks produced by causes purely beyond human control.
2. Wrecks caused directly or indirectly by over insurance.
3. Wrecks caused by deviation of the compass.
4. Wrecks caused by errors of observation at sea.

Under the first head the result was reached that about 70 per cent. of wrecks arise from preventable causes. Under the second head the result is found that more than three times as many insured as uninsured vessels are wrecked. Under the third division an abstract of the discussion of the problem of variation of the compass, both in wooden and iron ships, is given. Under the fourth division the two essentially different methods of finding the longitude at sea, viz.: the method by lunar distances and by chronometers, are explained and discussed, to ascertain which is the most accurate. From several hundred observations of each class the following tabular results were obtained:

Place and Circumstances of Observation.	Average error.	Range of error.	Coefficient.
	Miles.	Miles.	
Greenwich, Edinburgh, observations at each station, comparison of final results with truth.....	0.6	2 1	3 5
Washington, Greenwich, same as above	0.6	1.6	2.7
	0.6	1.8	3.1
Hudson, Greenwich, observations at each station, comparison with final mean	1.5	4.3	2 9
Brussels, Greenwich, same as above.	1.2	4 4	3.7
Places in Turkey by Struve, same as above	1.7	6.9	4.2
	1 4	4 8	3.6
Camp Riley, tabular places of moon.	3.5	13.8	3 9
Willet's Point, American ephemeris.	2.3	10.8	4.7
Willet's Point, British ephemeris ..	3.5	13.8	4.0
	3.1	12.8	4 2
Willet's Point lunars	10.2	24.2	2.4
Fisher's observations at sea	......	25.0	....

The error of chronometers is then discussed in a similar manner, after a discussion of the various sources of error:

1. The rates of the best chronometers of 14 makers, left for trial at Greenwich Observatory, between 1842 and 1871, are discussed with the following results, calling minutes of arc miles:

Greatest change of daily rate in about six months:

		Miles.
1842-53... 33	equal at end of 20 days.	16.5
1853-62....38		19.0
1863-71....25		15.5

Greatest change of daily rate between one week and next:

1842-53....19	equal at end of 20 days.	95
1853-62....19		95
1863-71....13		65

In order to show the great influence of temperature on rates, a discussion similar to the above is made of the finest and poorest chronometers left for trial between 1867 and 1871, selecting the four weeks of ordinary temperature immediately preceding four weeks of high temperature. The results are:

	Miles.
From mean of best chronometer at end of 20 days' error	29.0
From mean of poorest chronometer at end of 20 days' error	17.6

But the poorest chronometers are good compared with sea-going ones.

Combining the results, we find that the navigator must expect for his chronometer at the end of twenty days about an error of 3.6 miles, he must be on the lookout for an error at 11.5 miles, and he need not be surprised at an error of 21 miles, all on the supposition that he has only an average chronometer.

Attention is called to the great error arising from using an average rate for a whole voyage instead of rates for various temperatures.

The paper closes with a discussion of sextant observations on shore and at sea, from observations available between 1793 and 1871, arriving at the conclusion that under the most favorable circumstances the errors of observation alone are likely to exceed 2 miles, while ordinarily they are much larger. These errors are independent from chronometer errors, and must be added to them.

From a discussion of the results of 37 cases of runs for longitude of sea stations, mostly by British exploring expeditions, the following final results are found:

	Miles.
Mean error at end 11 days	4.4
Range of error	15.1
Average error of longitude	5.0
Greatest range between results	31.6

It is therefore safe to assert that a navigator who assumes that he can get the place of his ship certainly within 5 miles, or probably within 15 miles, exhibits an over-confidence which may lead him to ruin.

CALORIMETER IN LOCOMOTIVE ENGINE BOILERS.

From "The Engineer."

In a recent impression, when considering some of the peculiarities of the locomotives exhibited at Vienna and used on the Continent, we called attention to the enormous length of fire-tube adopted on many French, German, and Austrian railways, and we stated that these long tubes were rendered necessary because of the small area which they presented for the passage of the products of combustion as compared with the grate surface. The question thus raised is one of peculiar interest because tube surface is very expensive to construct and maintain, and we have reason to believe that most locomotive superintendents would willingly reduce it below existing limits if they deemed such a reduction consistent with economy of fuel. We shall not pretend to dogmatize on a question the true solution of which can only be reached by experiment, but we venture to think that time will not be wasted if we consider the problem even on a theoretical basis, so long as there is nothing in the theory absolutely inconsistent with practice.

It has long been known that the calorimeter—in other words, the gross aggregate area of escape through the flues of a boiler—exerts a very important influence on the quantity of fuel required to generate a given weight of steam. Very elaborate experiments have been carried out in this country and in the United States in order to arrive, if possible, at some law or rule on which to base the proportions which the calorimeter of a boiler should bear to the grate surface, but the attempt has not succeeded. All that is known certainly is that there is better area of calorimeter than any other for each particular boiler, for each particular duty exacted from that boiler, and for each particular coal used. Therefore no general law can be laid down. If, however, the coal and the duty are known, then it is possible to decide what is the best calorimeter. Now, on most railways the work to be done by locomotives of a given class varies only within moderate limits, and the coal used is of very uniform quality. It appears, therefore, to be quite possible to decide by experiment what is the best calorimeter for each type of engine, and we have no doubt, as in a very large number of cases the calorimeter is not just what it ought to be, that, therefore, simple experiments would give information which could not fail to prove useful, and result in a saving of fuel. There are two points to be considered in dealing with this question. The first is, that if the calorimeter is made small, the velocity of the escaping products of combustion through the tube must be augmented. The second is, that if the calorimeter is made too great the gases are not retained sufficiently long in the fire-box, and much of its surface is rendered useless, principally because it is never filled by the flame, and the hinder surface, especially that nearest the fire-door, is reduced in efficiency. Besides this, the tubes will not be completely filled with hot gas, and a great deal of their surface will practically be wasted. In theory, the more slowly the heated gas can be made to traverse the tubes the better, but in practice it is found to be difficult to induce the gases to pass slowly and equally through all the tubes at different levels where so many are used, and in any case there is a strong tendency to deposit soot within them, which is eminently objectionable. It would appear, therefore, that upon the whole, regarding the problem from a strictly theoretical point of view, it is the best plan to use in locomotives very long tubes of moderate diameter—say two inches—and not to have more of them than will suffice to give a very small calorimeter. This is the principle generally adopted by Continental engineers. It is true that they are influenced in adopting this system by other considerations than those of economy of fuel, such, for instance, as the difficulty of getting more calorimeter if they wanted it; but the fact still remains, that the Continental system of constructing locomotive boilers supplies us with a distinct type possessing many advantages, whether that type has been forced upon its designers or been willingly, as we believe, adopted; and it will be found that within tolerably close limits, engineers, both here and abroad, have adopted similar proportions of tube to grate surface, the calorimeter also bearing such a relation to the tube length that the time occupied by the heated gas in escaping to the chimney will be nearly the same, although the velocity of the gas in the foreign is much greater than in the native or indigenous locomotive. For example: the great Semmering engine, which we illustrated in our last impression, has a grate surface of a little over 23 ft., and a calorimeter through the body of the tubes and neglecting ferrules, of about 553.5 sq. in., or in round numbers the calorimeter is one-sixth of the grate used. We may compare these figures with those supplied by a very usual English type of goods engine, with 207 tubes 2 in. in diameter, and 16 sq. ft. of grate, the tubes being about 11 ft. 6 in. long, as against 15 ft. 7½ in. in the Semmering engine. The calorimeter in this case is abouth one-fourth of the grate surface, or one-third greater than in the Semmering engine; but the tubes in the latter are not quite one-half longer than in the English engine. A comparison, however, of a number of Continental engines having long tubes with a number of English engines having tubes of about the normal length, goes to show that, as we have stated, the velocity of the gas in the Continental engines is about as much greater than it is in our engines in the same proportion that the tubes are longer. From this it results that less soot should be deposited in the smaller tubes, the tubes are better filled with gas, and the conditions of heat surrender are probably better. But on the other hand, the first cost of the boiler, and its weight, and expense of maintenance, are much increased. It is not easy, nevertheless, to say exactly at what point further augmentation of tube length ceases to pay; and it is possible that Continental engineers err in making tubes too long, while in this country we err in making them too short. A long tube requires more draught and causes more back pressure than a short one, other things being equal. But a boiler with short tubes, on the other hand, may waste so much heat, because of the escape of the gas uncooled, that a sharp draught may be essential to keep up steam, and thus all the evils of both too long and too short a tube may be met with in one and the same engine.

If we suppose the soot difficulty to be disposed of, it admits, in the same way, we think, of being proved that, provided a very accurate distribution of the gas is effected, the nominal calorimeter of a boiler may be greatly increased, while the tubes are shortened, with much advantage. Now, a good deal depends on the fact that it is possible to retain the products of combustion for as long a time as we please in the furnace, and to make the rate of combustion what we like, within limits, without regard to the diameter or length of tube. If, then, while retaining a given current of air through the bars, we reduce the velocity through the tubes, we may reduce the tube length nearly in the same proportion. Thus, let the velocity of escape in one boiler with 2 in. tubes 12 ft. long, be 40 ft. per sec., then, by constructing another boiler with twice as many tubes half the length, the velocity would be reduced one half; but the economic efficiency of the boiler may be just as great, and there is no doubt that it would be as great, because portable engines with short wide tubes and an enormous nominal calorimeter excel most locomotives in economy of fuel, as has been proved time and again by the Royal Agricultural Society's trials. The great difficulty standing in the way of using short tubes and many of them, of good size, lies in the increase which would be required in the diameter of the boiler, and in the difficulty of making the gases distribute themselves equally. There is reason to think, however, that in many cases, and especially for working inclines, boilers with large barrels, say as much as 5 ft. in diameter, might be employed with advantage, the large nominal calorimeter which would be secured by a multitude of tubes, being reduced to a comparatively small true calorimeter by the use of ferrules at the smoke-box end, such as those employed by makers of racing portables. Be this as it may, we venture to think that any locomotive superintendent who has engines daily doing much the same work, may with much advantage carry out a simple experiment, by trying for a month at a time the effect produced in the consumption of fuel by the use of ferrules of varying thicknesses in the smoke-box. We are not aware that anything like a good set of experiments of the kind has been instituted in this country since coal came to be used as fuel on railways; and this is remarkable, because the cost of the experiment would be little or nothing, and the information to be obtained by it could not fail to prove valuable.

APPLIED ELECTRICITY.

A recent publication* reminds us that the application of electricity to its several practical purposes has risen to the rank of a distinct branch of engineering. A special training, as decided in character as that for a hydraulic or consulting steam engineer, is required in him who aspires to the position of an expert in electrical applications.

Electrical science now presents its own system of measures, together with both theoretical and empirical formulas for convenient use.

Our school text-books give no hints of such a branch of applied science. Popular scientific treatises on electricity bear about the same relation to the books for the electrician that descriptions of scenery along our rivers bear to hydraulic engineering. They serve to blind the novice to the fact that there is an economic value having some relation to the attractive phenomena.

The condition of our instruction books in this regard is just now eminently unsatisfactory. The books designed for the worker in this new field are far more *scientific* than those prepared for the student.

It is not a matter for surprise that the electrician requires instruments of peculiar construction, designed for measurement in his particular branch of industry, nor that he needs a table-book, looking much like that prepared for the railway surveyor, for these are necessities of a natural growth.

The little work of Mr. Haskins is evidently designed for just such frequent use as are any of the engineers' Pocket-Table-Books. In consequence, however, of the paucity of information within reach of the young learner, the author judiciously gives a brief outline of applied electrical science. We quote the book so for as to include the description of the instruments employed.

"To enable the student to work understandingly in galvanometric measurements, it is necessary that he should comprehend

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* The Galvanometer and its Uses. A manual for Electricians and Students by C. H. Haskins. New York: D Van Nostrand.

the laws upon which such measurements are based.

"These laws we will state, in as few and simple words as possible; and the student, if he masters them thoroughly, will be enabled to understand readily what follows.

"All conductors offer a certain degree of *resistance* to the passage of the electric current through their substance. This resistance varies with defferent materials. The following table illustrates the comparative resistances of the most common metals to the passage of the current, silver being taken as the standard. The measurements are taken at 32 deg. Fahr.

Silver, hard	100
Copper, hard	100
Gold, hard	128
Iron	594
Tin	809
Lead	1202
Brass	450
German Silver	1282
Platinum and Silver	1493
Mercury	5815

Jenkin.

The resistance of metals increases with their thermometric heat. For instance, iron wire increases about .35 per cent. for each degree Fahrenheit above 60 deg.

"The conductivity (which is the reverse of resistance) of soft iron wire, suitable for telegraph purposes, is about $\frac{1}{6}$ that of commercial copper wire.

"The conductivity of any wire increases as its weight per foot.

"The resistance of any iron wire, per mile, is found by dividing 360,000 by the square of its diameter. The quotient will be in ohms at 60° Fahrenheit. This is expressed thus $\frac{360,000}{d^2}$, d being the diameter of the wire. Or it may be measured, as hereafter explained.

"Knowing, then, the resistance, per mile, that a given wire offers, or should offer, to the passage of a current, we have a basis for comparison, and can readily ascertain its electrical condition, and, when defective, apply a remedy where and when required.

"To determine accurately the amount or degree of resistance, we must have some standard that will serve us as the inch does in the measurement of distance, or a grain in estimating weight. Several of these standards have been made.

"But two standards, however, are now in general use, and these two only shall we note here.

"The Ohm is the standard unit, adopted by the British Association, and in general use in this country. It is equal to the resistance of a prism of pure mercury of 1 square millimetre section and 1.0486 metres length, at 32 deg. F.

"The Siemens Unit is equal to the resistance of a prism of pure mercury of 1 square millimetre section, and 1 metre long, at 32 deg. F. The Siemens Unit is in general use on the European continent, and to a considerable degree in the United States.

"To convert Siemens into Ohms, multiply by the decimal .9536.

"To convert Ohms into Siemens, multiply by 1.0486.

"Having found our units of measurement, we will now consider the laws governing the flow of the current.*

"The power which a cell of battery possesses of causing the transfer of its current from one place to another, is its electromotive force. In other words, the electromotive force of a current is its power of overcoming resistance—its energy. To use a familiar comparison, electromotive force is to a current what pressure is to steam.

"The amount of current that is evolved in a given time by a cell of battery is termed its quantity. This amount may be increased or diminished by lessening or increasing the resistance in circuit both in the battery and external thereto.

"While chemical action is going on in a battery, the current is being constantly accumulated, or piled up, at the positive pole of the battery, with a vigor depending entirely upon the electromotive force of the battery.

"The old theory, that the current thus accumulated flowed along the line-wire to the ground at the distant end, and back to the other terminal of the battery through the ground, is now generally abandoned, and the theory of M. Gavarret accepted as correct.

"He teaches that the earth, being a common receptacle and reservoir of electricity —hence termed the 'common reservoir'— has no electrical tension.

"When the current in a battery accumulates at the positive pole of the battery, its tension is greater than that of the earth.

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* In examples given in this work, the term "unit" is used as a "unit of measurement," and may be read either as an Ohm or Siemens unit. When absolute measurements are given, the word Ohm or Siemens is always given to distinguish the kind of unit meant.

Now connect a wire from each end of the battery to the ground. If these wires are short and thick, thus having practically no resistance, the current will flow from the positive pole of the battery through the wire to the earth with a degree of energy depending upon its excess of tension over that of the earth. This action will continue, the earth receiving and absorbing from the positive pole of the battery where the tension is greater, and giving to the negative pole where the tension is less, until the action of the battery ceases from exhaustion, and the tension of the battery and the earth are equal.

" The effort, then, of the current evolved by the battery, is to equalize the tension or pressure, and produce an electrical equilibrium. This same inequality of tension between the clouds and the earth, is the cause of lightning-storms.

" If, in the case above supposed, the wires connecting the battery with the earth, were so long, or so thin, as to interpose considerable resistance to the passage of the current, the flow would be less in amount, and the chemical action of the battery less rapid—the current being dammed, or choked back, by the resistance to its passage.

" The amount of current, then, that will flow to line, depends upon and is proportionate to the resistance of the circuit. Hence, Ohm's law, which is the foundation of all electrical measurements.

Ohm's law is stated thus :

C being the amount of current,
E the electromotive force, and
R the resistance in the circuit.

$$C = \frac{E}{R}$$

or, the current flowing to line, equals the electromotive force divided by the resistance.

" The amount of current generated by a cell of battery depends upon the size of its plates—the tension, upon the number of cells.

" Hence, a battery of 40 cells, while giving 40 times the electromotive force, or tension * of one cell, will furnish only the same amount or quantity of current. Each cup of battery has its own quantity, which is urged forward to the next cell, by virtue of its own electromotive force. The current from the cell at the positive pole of the battery, is pushed out to the line wire, the current from the next cell taking its place—the last cell being supplied, through the ground-wire, from the earth. But the current from each cell, when carried forward to its neighbor, parts with its energy or electromotive force; and the current from the first cell is pushed forward to line, and thence to the ground at the further end of the line, with all the electromotive force, or energy, of all the cells.

" The amount of current flowing to line, from a given battery, is regulated, as we have seen, by the resistance of the circuit —and in this must be included the internal resistance of each cell of the battery. But, with a given total resistance, the flow of current may be increased.

" 1st. By increasing the size of the cells, and thus decreasing the total resistance in the circuit; and,

" 2d. By adding more cells.

" If we consider only the internal resistance of the cells, the addition of more cells will not increase the current.

" Thus, if we have 1 cell of battery, with an internal resistance of 2 units, and an electromotive force of, say, 10, and the poles connected by a wire having practically no resistance, the proportion of current flowing to line will be 5.

$$\frac{E = 10}{R = 2} = 5.$$

Now take 5 cells,

$$\frac{E = 5 \times 10 = 50}{R = 5 \times 2 = 10} = 5.$$

" The product is still 5, because the divisor and dividend are both changed in the same ratio.

" But suppose the resistance of the line-wire to be 5 units, represented by r. Then with 1 cell we have,

$$\frac{E = 10}{R + r = 7} = 1.43,$$

and with 5 cells,

$$\frac{E = 50}{R + r = 15} = 3.33,$$

or nearly three times as much current as before.

" It will be seen, therefore, that the proper method for adapting a battery to any line, with any instruments, is to select a form of battery giving sufficient current to saturate the magnets of the relays to their maximum, and then add a sufficient

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* Electromotive force may be defined as tension in a state of motion; and tension, as electromotive force in a state of rest.

number of cells, to drive it with the necessary force to produce the desired effect.

"The sum of the resistances of all the instruments in a circuit, should, as nearly as practicable, balance the resistance of the line-wire. In no case should they exceed the wire resistance.

"'When the resistance of the coils of the electro-magnet is equal to the resistance of the rest of the circuit, *i. e.*, the conducting wire and battery, the magnetic force is a maximum.'—(Noad's Text Book.)

"'The application of this law to a telegraphic circuit would be to make the sum of the resistances of all the magnet-coils in circuit, equal to the resistance of the line and batteries; but as in practice the resistance of a telegraphic circuit varies, being considerably reduced by defective insulation, the total resistance of the instruments should be less than that of the line when in good condition, to attain the best results during unfavorable weather.'—(Pope's Modern Practice, page 152.)

"A safe, practical rule for determining the number of cups of main battery needed, is to call the resistance of the relays equal to the line-wire, and use one cup of Grove, or bichromate of potash (electropoion), or two cells of Calland or Hill battery to each 100 units resistance in the circuit.

"Thus, for example: suppose a circuit of 200 miles No. 9 wire.

This will measure 20 units to the mile, or....	4000 units.
8 relays in circuit, 500 units each...........	4000 "
Total resistance.......................	8000 "

"For Grove or bichromate, divide by 100, and we get 80 cups battery, 40 at each terminal of the wire. For sulphate copper battery, divide by 50, and we find that we need 160 cups of battery, 80 at each end.

"These figures are true only of single wires. When several wires are worked from one battery, the total amount of battery used is of course much less. The number of lines—of about equal resistance—that may be worked from the same battery, varies greatly with different batteries, depending upon the chemical energy of the battery, the quantity of current evolved by it, and its liability to polarization.

"Thus the bichromate batteries of 80 cups, that we determined upon for our 8,000 unit line, will furnish current enough for several lines of the same resistance. But as we add wires we lessen the external resistance, until, owing to the slight resistance, the action is so rapid that the battery polarizes and action ceases. Practically, not over six to eight lines can be worked from this battery.

"With Grove it is different. Lines may be added to a Grove battery, with perfect safety, up to forty or fifty.

"The sulphate copper batteries have too much internal resistance to allow the addition of many wires. Three lines are worked from sulphate copper batteries having jars 6 in. in diameter.

In all cases, the expenditure or consumption of material in a battery is in exact proportion to the work done; that is, to the current evolved. Therefore, the expenditure of battery material, with three lines to a battery, is three times that of one line to the same battery, and there is no economy in working several lines from one battery, except in room occupied.

"The disadvantage of working several lines from one battery is the interference of the circuits with each other in bad weather. Sometimes this interference is quite serious. A greater number of cells of battery than is absolutely needed to work the circuit promptly, is injurious, and in wet weather, it tends to make the line work badly. Indeed, the effect of an excess of battery is often as detrimental to a line in wet weather as bad insulation, or a conducting wire of too high resistance.

"To explain this, the reader will remember that the difference in resistance between the line-wire and the insulators, is the margin upon which the line is worked. If that margin is diminished by bad insulation, a portion of the current escapes to the ground. If the resistance of the line-wire is increased, the margin is again diminished, and a portion of the current escapes as before.

"Now, the higher the tension of the battery current, the more readily will it escape from the line, because the greater is its power to overcome resistance. The effect, then, upon a wet day, is the same upon the line whether the insulation is defective, or the battery too large.*

"Thus it will be seen that adding more battery to a heavy-working line, will often,

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†If, however, the escape is not very serious, it is sometimes beneficial to add battery to sending end until you have so high a current that, in addition to the large amount escaping, enough will reach the further end to work the relay. In this case the receiver must not attempt to "break."

in wet weather, make it work worse than before. And it will also be noted, that relays of high resistance, as they add to the resistance of the line-wire, decrease the working margin between the line and insulator resistance, and thus increase the tendency of the current to escape.

"When the relays of a line, of say 200 miles, are proportioned to the line itself, that is, do not exceed the line-wire resistance, and the battery is adapted to the circuit by the rule above given, if the line is well insulated, it will work well, in very bad weather, when a similar line, equipped with high resistance relays, or an excess of battery, will scarcely work at all.[*]

"Many experiments have been made to determine the speed of transmission of the electric current or influence through a wire. The first measurement, made by Wheatstone in 1833, showing a speed of 288,000 miles per second, was taken as the speed of the current under all circumstances. Subsequent measurements, however, showed such variable results, that confidence in Wheatstone's figures was much shaken. The following table shows the rates of speed noted by various experimenters:

Date.	Length of Circuit.	Velocity per Second	Observer.	Remarks.
1833	5 mile	288,000	Wheatstone	Leyden Jar.
1849	880	18,700	Walker	Relay.
"	590	16,000	"	"
"	607	28,500	Mitchell	"
1850	260 iron	60,000	Fizeau & Gounelle	Galvanometer needle.
"	130 copper	114,000	" "	" "
"	1045	15,000	Gould	Relay.
"	447	17,000	Walker	"
"	230	13,000	"	Chemical Telegraph.
1854	104 iron	115,000	Guilleman & Burnouf	Galvanometer needle.

"The above table gives no data from which to make any calculation or deduce any law. It only serves to show how varied were the results obtained. To be of any benefit, the experimenters should have given the conductivity, per mile, of the wire used, the form of battery, and the number of cells used in each case. The English, French, and German experimenters use, also, miles of different lengths.

"Thus, for land lines, we were without any reliable data until 1869, when Prof. G. W. Hough, of Dudley Observatory, and Mr. C. S. Jones, of Albany, New York, undertook a series of experiments to determine the velocity of the current. Mr. Jones, manager of the Western Union office, by looping wires to Boston, Detroit, New York, and Buffalo, obtained circuits of sufficient length to test the question thoroughly.

"As Grove battery was used, and the line-wire was galvanized No. 9, we have some data from which to draw satisfactory conclusions.

"On the 27th of May, Messrs. Hough and Jones obtained the following results:

Velocity per Second.	No. Cells of Battery.	Length of Circuit.
10,200 miles.	70	400 miles.
20 000 "	160	400 "
29,450 "	295	400 "
18,200 "	295	1000 "

"Prof. Hough remarks, in relation to the above results:

"'An inspection of these results show at a glance, that the velocity increases with the number of battery elements employed; also, for the same battery it decreases with the length of the circuit.'

"From these figures we deduce these facts:

"*First.*—That with a given resistance, the speed increases with the increase of the electromotive force, *i. e.*, the power to overcome resistance and urge the current forward.

"*Second.*—That with a given battery, the speed of the current varies as the re-

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[*] A line that is suffering from bad escape may be worked much better for through business in bad weather, by switching off the battery at the receiving end of the line, and receiving only by the sending office current. Because, if there are heavy escapes on the line, the sending operator does not break all the current from the battery at the receiving end of the line, thus leaving the receiving relay partially magnetized constantly, and consequently less sensitive to the small portion of current from the sender that reaches the receiving station. Whereas, if the only current on the wire is that of the sender, the portion of his current that does reach the other end of the line comes clear and sharp.

sistance to be overcome in the circuit varies.

"And these facts explain why Wheatstone obtained a velocity of 288,000 miles per second, when Hough and Jones show less than 30,000 miles as their greatest velocity. Wheatstone used a Leyden jar, discharging a current therefrom of the higest tension, and having but a half mile of resistance of circuit, while the Albany experiments were made through long circuits, with battery-currents of comparatively very low tension.

"The effect of a moist or dry atmosphere on line measurements is too generally overlooked, especially on lines insulated with glass. As an insulator, glass is probably the best in dry weather, as it is certainly one of the worst when surrounded by a saturated atmosphere. Being an excellent radiator of heat, the glass insulator readily gives it out to the passing breeze, and speedily becomes cold, when the particles of moisture held in suspension in the air are deposited in a condensed form on the surface of the glass, thus forming a film of water, through which the current escapes.

"Again, even with the most perfect insulation, with a saturated atmosphere, a line will show considerable general escape. Frequently, a lower degree of insulation is shown just before a heavy rain than after it begins falling. And although the most careful experiments fail to show any escape through the atmosphere from one particle of moisture to another, yet this heavy escape is often noted, as above stated. When the rain begins falling, the moisture being condensed into drops, the continuity of the moisture seems destroyed, and the escape consequently checked.

"Whenever practicable, then, the percentage of saturation of the atmosphere, shown by a hygrometer, should be recorded, with the measurement, for future use, in comparing the condition of a line at different times.

"By attaching a second wire to a battery, a second path is provided for the current, and the resistance to its flow therefore lessened. If both wires are of exactly the same resistance, the effect is the same as if the first wire were taken off and replaced with one of just double the capacity, or weight per foot, or one of half its length of the same capacity.

"The joint resistance—that is, the resistance of all the wires attached to a battery—to the flow of its current, may be found as follows:

"If the resistance of the wires is equal, the sum of the resistances, divided by the square of their number, or the resistance of one wire, divided by the number of wires, will give the joint resistance.

"Thus, four wires of 100 ohms each:

1st method,

$$\frac{400}{16} = 25 \text{ ohms.}$$

2d method,

$$\frac{100}{4} = 25 \text{ ohms.}$$

"When the resistance of two wires is unequal, the resistance may be found by dividing their product by their sum.

"Suppose two wires of 200 and 300 ohms resistance,

$$\frac{200 \times 300}{200 + 300} = \frac{60,000}{500} = 120 \text{ ohms.}$$

"When more than two wires, find the joint resistance of the first two, as above; then take the result, considering it as a single wire, and proceed in the same manner.

"Suppose we have three wires, of 200, 300, and 280 ohms. The joint resistance of the first and second is, as we have seen, 120 ohms.

$$\frac{120 \times 280}{120 + 280} = \frac{33.600}{400} = 84 \text{ ohms,}$$

the joint resistance of the three wires.

"Or it may be obtained by the following formula:

"1st. Calling the three wires a, b, c,

$$\frac{abc}{ab + ac + bc}.$$

$$\frac{200 \times 300 \times 280}{200 \times 300 + 200 \times 280 + 300 \times 280} = 84 \text{ ohms.}$$

"2d. Divide one by the sum of the reciprocals * of their several resistances.

$$\frac{1}{\frac{1}{a} + \frac{1}{b} + \frac{1}{c}}$$

The reciprocal of 200 is.............	.005
" " " 300 is.............	.00333 +
" " " 280 is.............	.00357 +
	.01190

and,

$$\frac{1}{.01190} = 84 \text{ ohms.}$$

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* The reciprocal of a number is the quotient of 1 divided by that number. Thus the reciprocal of 2, is $\frac{5}{10}$; of 20 is $\frac{5}{100}$.

"A magnetic needle will be deflected from the north by a current of electricity flowing in a conductor placed parallel to it. If the conductor is placed on top of the needle, and parallel, when the positive pole of the battery is attached to the south end of the conductor, and its negative end to the north end, the current will flow northward, and the north end of the needle will be deflected to the left. Reverse the current, and the north end will be deflected to the right. If the conductor is placed under the needle, the action will be in the reverse direction.

"The degree of deflection will be proportional to the strength of the current.

"If the conductor is carried over the face of the needle, and back underneath, the effect will be doubled. Wind the wire in several convolutions parallel to the needle, making a helix, with the needle in the centre, and you have the strongest form of galvanometer. The finer the wire, and the greater the number of convolutions, the more sensitive will the needle be to the current passing through the wire of the helix.

"By using fine German-silver or silver and platinum wire, the resistance of which is not affected by changes of temperature, we may make a series of coils whose resistance is equivalent to that of any number of miles, or fractions of miles. A number of these coils, arranged to be thrown in and out of circuit at pleasure, is termed a *Rheostat.*

"It is sometimes necessary, in measurements, to divert a portion of the current from a galvanometer, to reduce the deflection of the needle within proper limits. In this case, a wire or coil of greater or less resistance is used, which is connected to both posts of the instrument to be shunted. The current will then divide inversely as the resistance of the two paths or routes open to it. Suppose a galvanometer coil to have a resistance of 99 ohms, and the shunt-wire of 1 ohm. Then $\frac{99}{100}$ of the current would pass through the shunt wire, and $\frac{1}{100}$ through the galvanometer.

"In this case, the result shown by the galvanometer must be multiplied by the shunt to obtain the correct answer.

TANGENT GALVANOMETER.

"The intensity of the current, as measured by the tangent galvanometer, is proportioned to the tangent of angle of deflection of the needle.

"'Bradley's Improved Tangent Galvanometer' is the only one in use in the United States for line work, and is undoubtedly the most accurate tangent instrument made. We quote the description from Dr. Bradley's pamphlet. The needle is a peculiar one, being composed of 3 or more parallel strips of steel, mounted upon a ring of aluminum, and trimmed to form a circle. Long aluminum pointers are attached to this disk. The needle is balanced upon a steel point, on which rests an agate. The weight of the needle is only 20 grains.

"The coils are so placed that the current runs parallel with the meridian of the needle. They are $\frac{1}{2}$ in. or more wider than the diameter of the disk. By this means all parts of the steel composing the needle are subjected to the same inductive influence in all its deflections.

"It is a condition indispensable in the construction of a true tangent galvanometer, that the current through the coil should act as uniformly upon the needle in all its deflections as the earth's magnetism does; a narrow coil under a long needle does not fulfil this condition; for, as the extremities of the needle in its deflections pass more and more away from the coil, the inductive influence is less and less, as compared with the earth's influence.

"On the contrary, if we place a very broad coil under a long needle, the same difficulty occurs, but in the opposite direction. While the needle is on the meridian it is under the influence of but few convolutions, in the middle of the coil, but as it deflects it comes under the influence of an increasing number of convolutions, and therefore the influence is more and more increased.

"It being evident that the truth lay between these extremes, the expedient of a needle in the form above described was resorted to, and with entire success, for in this the condition sought is accurately fulfilled.

"Coil No. 1 is composed of very fine copper wire, wound evenly back and forth over the whole width of the coil, and of a sufficient number of layers to give a resistance of 150 or more ohms.

"Coil No. 2 is of 30 wire wound in the same manner, and to twenty-five or thirty ohms resistance. No. 3 is of two layers of No. 23 wire, giving one to two ohms resistance. And No. 4 is a strip of sheet copper of the width of the coils, and wound three and a half times around, so that the current passes four times under the needle; the resistance of this may be considered as null, or not sufficient to be noticed or taken into account.

"The outer ends of all the coils are connected with a common screw-cup, while the inner ones are connected each with its cup bearing its proper number.

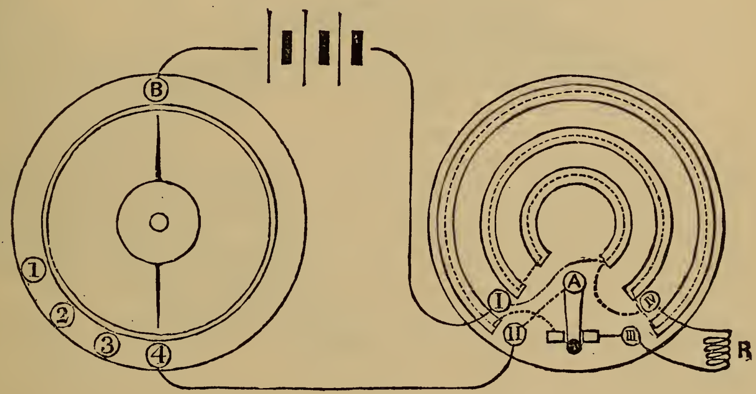
"Coil No. 1 is for currents of high intensity, No. 4 for those of great quantity, and Nos. 2 and 3 are for mixed or intermediate currents.

"The Rheostat contains coils whose several resistances range from $\frac{1}{100}$ of an ohm to 4,000 ohms, any one or more of which may be thrown into the circuit by removing the proper plug or plugs on the top of the rheostat, so that any resistance may be introduced from $\frac{1}{100}$ of an ohm to 10,000 ohms.

"In addition to two screw-cups [I. and II.] for connection with the battery and galvonometer, there are two other screw-cups [III. and IV.] for connection of any conductor whose resistance it is intended to measure; also a switch, A, on the rheostat, so arranged that the battery may be thrown through the rheostat or the conductor.

"Connections for Measurement.—Connect line or instrument-wires to be measured, to posts III. and IV. of the rheostat, one pole of the battery to B, on the galvanometer, and the other to I., on the rheostat. The wire leading from II. of the rheostat, is connected with 1, 2, 3, or 4, of the galvonometer, depending upon the coil to be used. Push the switch A to the right, throwing the current through the wire to be measured. Note the deflection of the needle. Now push A to the left-hand plate, throwing the current through the rheostat. Remove plugs, thus letting resistance into circuit, until the needle shows the same deflection. Add the figures marked on the holes unplugged, and you have your resistance in ohms.

Fig. 1.



"When you measure a wire put to ground at distant end, connect as before, except that you put a ground-wire to post IV. and line to III. Manipulate as before.

"Testing for Insulation.—First unplug 10,000 ohms resistance, using galvanometer coil No. 1. Note the deflection with the current through the 10,000 ohms. Call this the 'maximum of the galvanometer.' Now switch to the line (which is open at the farther end), and note the deflection again. (The better the insulation of line the less the deflection.)

"Suppose the deflection with the 10,000 ohms of the rheostat to be 30 deg., the tangent of which is .5774 *, while that through the line is 10 deg., the tangent of which is .1763.

"Now the tangent .5774 is to 10,000 ohms, as the tangent .1763 inversely is to the answer; or,

$$\frac{.5774 \times 10{,}000}{.1763} = .32{,}751 \text{ ohms.}$$

the insulation resistance of the line. This, multiplied by the number of miles, gives the mileage insulation, and this again, by the number of insulators per mile, the average resistance of each insulator.

"We give the above examples to show the method of using the instrument. Many of the formulæ given in this book may be

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* See table of tangents.

used for various measurements with this instrument.

GAUGAIN GALVANOMETER.

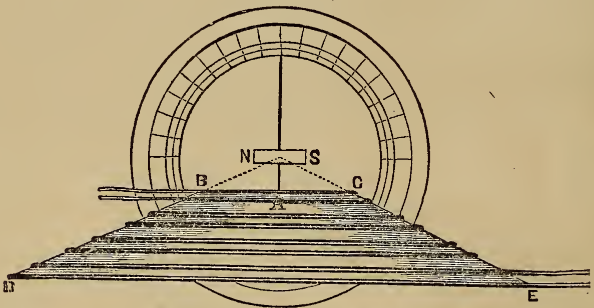
"This is also a tangent instrument, useful for measuring the electromotive force of batteries, their quantity and internal resistance. Its construction is in accordance with the following law:

"If a magnetized needle is submitted to the action of a circular current, placed in a magnetic meridian, when the centre of the needle occupies the summit of a cone, having for its base the circular current, the tangents of the angles of the deviation of the needle will be nearly proportional to the force of the current, when the height of the cone is equal to one-fourth of the diameter at its base. This theorem is correct within $\frac{1}{1300}$, when the needle is from 1.17 in. to 1.36 in. in length, and the coil not less in diameter than thrice the length of the needle."

"Fig. 2 (*a*, *b*) gives a plan and an elevation of this galvanometer.

"The wire forming the helix is generally wound in two parts of equal length and resistance, thus having an equal effect upon the needle. Thus this galvanometer may be used with both coils connected, and the indication given by the deflection as in a tangent instrument, or the resistance to be measured, may be connected with one-half, and a rheostat with the other, using it as a differential instrument.

Fig. 2 *a*).



PLAN OF GAUGAIN GALVANOMETER.

DIFFERENTIAL GALVANOMETER.

"In this form the needle is acted upon by two coils of equal length, resistance and power. The current leads to the coils on one wire, where it divides, passing around the needle in opposite directions. The resistance to be measured is attached to one coil, and the rheostat to the other. When the same amount of resistance is let into circuit in the rheostat, or its equivalent by shunting (see shunt), the effect upon the needle will be the same in each direction, and the needle will be brought to zero. Then the resistance shown in the rheostat (multiplied by the shunt, if one is used) gives the required information.

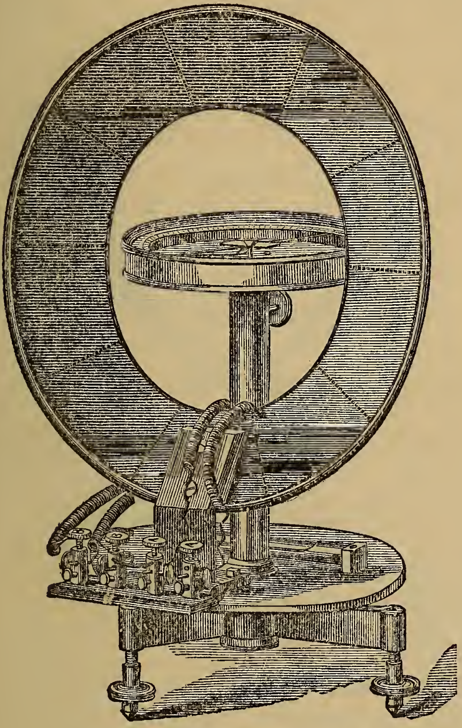
WHEATSTONE BRIDGE.

"In tangent and differential galvanometers the effect upon the needle is proportioned to the strength of the current, this being controlled, of course, by the resistance in circuit. The Wheatstone Bridge system of measurement is entirely different, its action being based upon the fall of tension of the current.

The fall of tension of a current from the pole of the battery to the wire terminal at the ground is, as we have shown, uniform. If, for a portion of the distance, we use two wires instead of one, the current will divide and flow by the two branches, and a point on one wire may be connected to a point on the other by a cross-wire, where the tension of the current is the same, without at all affecting the flow of current on the two lines. For, as the flow of current is caused by a difference of tension between the battery and the point with which it is connected by the line-wire, and as the tension of the currents at the two points on the wires connected by the cross-wire is the same, no current will flow through the cross-wire. And a galvanometer inserted in this cross-wire will, of course, show no deflection.

"In Fig. 3, suppose the current to start from E and flow to post 1. Here it divides, one-half passing by wire A, 3, B, to 2, and the rest by C, 4, D, to 2, and thence the current returns to battery. The resistance of the sides A and C, and B and D, being alike, the tension of the two portions of the current, at 3 and 4, is the same, and no current will pass across, from 3 to 4, through the galvanometer.

FIG. 2 (*b*).



ELEVATION OF GAUGAIN GALVANOMETER.

"Again: suppose we insert at A a resistance of 10, at B 100, at C 500, and at D 5,000. We shall find that the needle on the cross-wire still refuses to deflect. Because the current divides at 1, inversely as the resistance of the two routes 1, A, 3, and 1, C, 4; and the resistance at C being 50 times as great as at A, 50 parts of the current passed through A, with a resistance of 10, while 1 part passed through C with a resistance of 500. The tensions of the two portions, on arriving at 3 and 4, are the same, and as the same proportion as between A and C, is found between B and D, the divided portions pass on until they join at 2 and return to battery. Therefore, when A bears the same proportion to C, that B does to D, or when A : C : : B : D, no current will pass between 3 and 4.

"Now let us measure an unknown resistance which we will insert between the binding posts at D. Say we put 20 ohms in at C, and 1 at A. The needle is deflected strongly. Now insert resistance at B until the needle comes back to zero. Say it requires 250 units.

"Then,

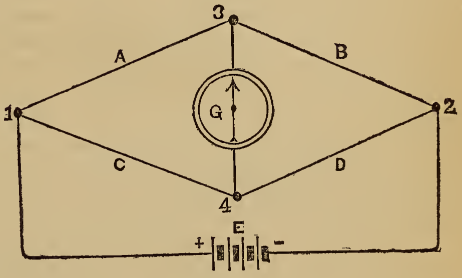
$$\frac{20 \times 250}{1} = 5000,$$

which is the resistance at D.

"If the resistance to be measured is small, you may insert equal amounts at A and C, and then the number of units inserted at B will exactly equal D.

"There are two forms of galvanometers in this country, made on the above principle: Siemens' and Gray & Barton's. The latter we will describe first, as its arrangement is similar to the diagram, Fig. 3.

FIG. 3.



"The battery-wire is led to a brass plate, on each side of which are smaller plates connected with resistance coils. By inserting plugs on each side of the battery-plate, the proportions of resistance between the first and second sides of the bridge (A and C, Fig. 3) may be varied at pleasure. The resistance to be measured is introduced at D, and a rheostat box at B.

"The Siemens galvanometer is entirely different in appearance, and although not as accurate as the Gray & Barton for small measurements, is much more convenient for general line-work, as it is portable, light, and convenient in form.

"The needle is made astatic. That is, two light needles are affixed rigidly to the same shaft. The two needles are polarized in different directions. One being slightly stronger than the other, the working effect or polarity of the pair is the difference in strength between them. This being very slight, the tendency to remain in the magnetic meridian is very feeble, and an extremely weak battery-current will cause a deflection. To increase still more the sensitiveness of the needle, it is suspended by a single fibre of untwisted cocoon silk. The lower needle hangs inside the coil, while the upper, which serves also for an indicator, hangs across the top of the dial. The dial and needle are covered with a glass case; surrounding the base of the glass horizontally is a slate disc, divided into 300 deg., running 150 from each side of the centre or 0 mark. Half embedded in the edge of this slate is a platinum or German-silver wire. This wire forms the first and second sides of the Wheatstone bridge—the A and C of Fig. 3.

"Pressing against this wire is a small platinum wheel with a vernier, on a movable arm. To this the battery-wire is connected. In the base of the instrument are three resistance-coils, 10, 100, and 1,000, either one of which is let into the third side (B, Fig. 3) by removing the plug which cuts it out. The resistance to be measured is introduced into side 4 (D, Fig. 3).

"The principle of measurement is precisely like that shown in Fig. 3; but in the Siemens, sides B and D being fixed, you vary the proportion between A and C until the proportion of the latter two is the same as the first two.

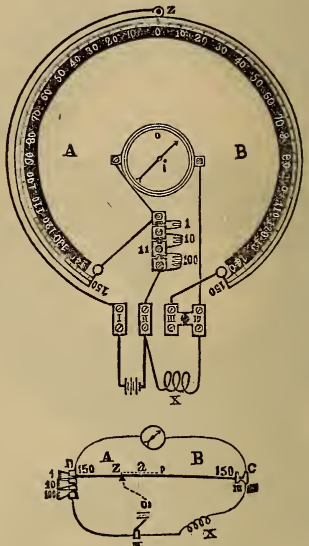
"The slate being divided into two parts by the divisions of 150 each, one side is marked A and the other B. Fig. 4 will show the connections. To measure the resistance of a relay, for instance, we connect the battery to posts I. and II., and the wires from the resistance to be measured to posts II. and IV. The plug remains in, between III. and IV. Remove the plug at 100.

"The current passes from post I. to roller Z. There it divides, one portion going by the wire on the edge of the slate, through the resistance coil 100 back to battery, by post II. The other portion of the current passes (on the B side of the slate) to posts III. and IV., thence out through the relay to be measured, and back to battery at post II.

"Remember, that the wire between the roller Z and 150, on one side of the slate, is the first side (A, Fig. 3); that between the roller and 150 on the opposite side corresponds with the second side (C, Fig. 3); the resistance 100 to post II., the third side (B, Fig. 3); and from post IV., through the relay to be measured, back to post II. (D, Fig. 3), is the fourth side; while from C, through the galvanometer, is the cross or bridge-wire.

"Now, when by moving the roller Z to the left or right, the proportion between the sides of the slate, A and B, is the same as between the resistance 100 and the relay to be measured, the needle will come to zero.

Fig. 4.



"Suppose that when the needle stands at 0, the wheel Z is at 50, on the A side of the slate. Then, as A is to B, so is 100 to X, the unknown resistance. There are 150 deg. on each half of the slate. Then the formula would read,

$$\frac{150+50}{150-50} \times 100 = X, \text{ or } \frac{200}{100} \times 100 = 200,$$

which is the resistance sought.

"When a line is to be measured, connect battery to post I., ground to II., and line to IV. The ground on post II. completes the circuits, as the line is grounded at distant end, and the other end of the battery is also grounded.

SINE GALVANOMETER.

"The strength of the current, in a sine galvanometer, is proportional to the sine of the angle of deflection. The Siemens may be used as a sine galvanometer by connecting the battery to post II., and line to be measured to IV., and unplugging between III. and IV. Set the needle in position; put the vernier-wheel at 0, on the slate.

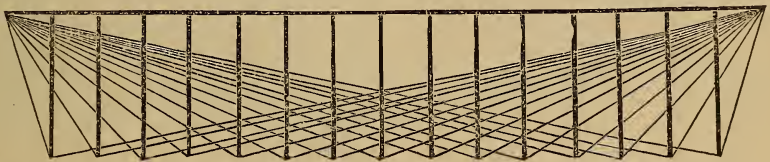
Now, when the needle is deflected, move the needle-coil by revolving the slate in the direction of the deflection of the needle. The coil is thus kept parallel with the needle, and its maximum effect exerted. When the needle is deflected to that point where the earth's attraction for the needle is exactly balanced by the effort of the coil-current to deflect it, the needle will become stationary. Now read the degree on the slate opposite the vernier, and a reference to the table of sines will give the sine of the deflection; and having previously taken the constant of your instrument—that is, having found to what sine it will deflect with a given resistance and a given battery—you have now a proportion giving you the result sought."

SOME OPEN QUESTIONS IN BRIDGE BUILDING.

Contributed to Van Nostrand's Magazine, by FREDERICK H. SMITH, C. E.

I.

The chord strain in a Bollman truss is determined by Molesworth in England, and Shreve and others in America, by the well-known formula $\frac{LW}{8D}$ = strain, uniform throughout the length of the chord, while Vose, Whipple, and others add together the horizontal resultants of all the tie strains, both main and counter, that pull against one end of the chord. That there is a great difference in the results of these methods, is best shown by a few figures, taking Shreve's Bollman truss example, shown on page 325, *et seq.*, of his treatise on "Bridges and Roofs," deck span 160 ft. long × 15 ft. deep, in 16 panels of 10 ft. each, gross load 240 tons or 15 tons per panel, two trusses in one.



In this truss the Molesworth and Shreve method gives, page 326,

$$\frac{240 \text{ tons} \times 160 \text{ ft.}}{8 \times 15 \text{ ft.}} = 320 \text{ tons chord strain,}$$

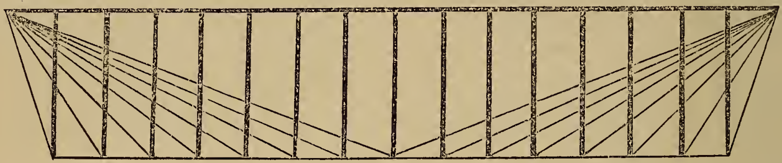
while the method of Vose and others gives

$15 \text{ tons} \times \frac{15}{16} \times \frac{10}{15} = 9.375$ tons chord strain.
+ " " $\times \frac{14}{16} \times \frac{20}{15} = 17.5$ " " "
+ " " $\times \frac{13}{16} \times \frac{30}{15} = 24.375$ " " "
+ " " $\times \frac{12}{16} \times \frac{40}{15} = 30.0$ " " "
+ " " $\times \frac{11}{16} \times \frac{50}{15} = 34.375$ " " "
+ " " $\times \frac{10}{16} \times \frac{60}{15} = 37.5$ " " "
+ " " $\times \frac{9}{16} \times \frac{70}{15} = 39.375$ " " "
+ " " $\times \frac{8}{16} \times \frac{80}{15} = 40.0$ " " "
+ " " $\times \frac{7}{16} \times \frac{90}{15} = 39.375$ " " "
+ " " $\times \frac{6}{16} \times \frac{100}{15} = 37.5$ " " "
+ " " $\times \frac{5}{16} \times \frac{110}{15} = 34.375$ " " "
+ " " $\times \frac{4}{16} \times \frac{120}{15} = 30.0$ " " "
+ " " $\times \frac{3}{16} \times \frac{130}{15} = 24\ 375$ " " "
+ " " $\times \frac{2}{16} \times \frac{140}{15} = 17.5$ " " "
+ " " $\times \frac{1}{16} \times \frac{150}{15} = 9.375$ " " "

Total........... 425.

Here is a difference of 105 tons of chord strain. Shreve explains his analysis on page 326 by saying: "Taking moments around a point in the centre of the truss, and in the line of the lower ends of the vertical braces, the strains in the inclined braces crossing the centre may be disregarded, as their amounts in opposite directions exactly balance each other." It is true enough that they do exactly balance each other, but it is not so clear that they may therefore be disregarded, as they can only strike that balance by pulling against each other through the chord, in precisely the same way that the balance is struck by those which do not cross the centre. The truss in question is in no sense a continuous beam, but simply an assemblage of independent triangles, in this case 15 in number, each triangle a complete truss in itself, exerting a chord strain for itself, as though there were 15 separate chords, side by side, in the span. There are thus 30 ties (or inclined braces) in the span, 15 at one end of the chord balancing 15 at the other, while Shreve's method only allows chord material for 8 ties at each end, thus leaving 7 ties at each end to pull against each other, but with no chord material to transmit their strains. When the span is loaded all the ties in it are at work at once, and if these 7 do not pull against the chord, what do they pull against? There is no anchorage to the masonry, and if the strains from 14 ties are to be disregarded because their amounts in opposite directions exactly balance each other, will not the same line of reasoning also do away with the strains from the remaining 16 ties?—for they likewise balance each other.

And furthermore the 8 ties that Shreve does count in, do not pull nearly so much as even the 320 tons given by the centre formula. They will not work by the process generalized in the phrase, "taking moments around a point in the centre," so long as the counter ties continue to carry to the farther pier, so much of each panel weight as is due to the leverage of the span at each post, *i. e.*, so long as the truss is a Bollman truss, but they can be made to strain the chord to 320 tons, only by abolishing the counter ties entirely, and substituting a bottom chord for them, thus throwing full panel weights through the main ties to the nearest pier. This change, however, makes not a Bollman but a beam truss of it, and the units of horizontal work done, or foot-tons in the two chords, are still the same as in the Bollman, as shown below.

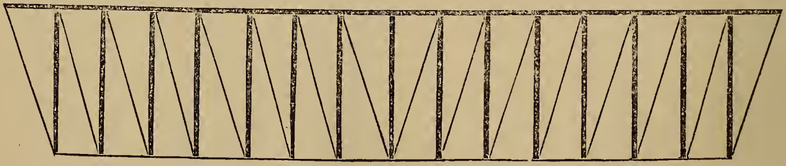


15 tons × $\frac{10}{15}$ = 10 tons × 140 ft. = 1400 ft.-tons.
" " × $\frac{20}{15}$ = 20 " × 120 " = 2400 "
" " × $\frac{30}{15}$ = 30 " × 100 " = 3000 "
" " × $\frac{40}{15}$ = 40 " × 80 " = 3200 "
" " × $\frac{50}{15}$ = 50 " × 60 " = 3000 "
" " × $\frac{60}{15}$ = 60 " × 40 " = 2400 "
" " × $\frac{70}{15}$ = 70 " × 20 " = 1400 "
7.5 " × $\frac{80}{15}$ = 40 " ×
Top chord str'n = 320 " × 160 " = 51200 "
Total units of work = 68000 "

which, if concentrated in one chord, gives

$$\frac{68000}{160} = 425 \text{ tons strain.}$$

This leads to a statement, which the writer believes has not been heretofore made, viz., that so long as the same panel data are preserved, the units of work done horizontally, or foot-tons, are the same in all systems of trussing, which fact affords a valuable check, and as such is submitted to the profession. In proof of its accuracy, the Fink truss, given by Shreve, page 332, is cited, in which the chord strain is shown to be 425 tons, using same data as the Bollman, referred to above, and, in further support, the chord strains of a simple quadrangular beam truss, reduced to foot-tons, are here given:



Tons. tons. ft. ft.-tons.
15 × 7.5 panels × $\frac{10}{15}$ = 75 × 40 = 3000
" × 14.0 " × " = 140 × " = 5600
" × 19.5 " × " = 195 × " = 7800
" × 24.0 " × " = 240 × " = 9600
" × 27.5 " × " = 275 × " = 11000
" × 30.0 " × " = 300 × " = 12000
" × 31.5 " × " = 315 × " = 12600
" × 32.0 " × " = 320 × 20 = 6400
Total units of horizontal work = 68000

which, concentrated in one chord, as in the Bollman or Fink trusses, gives 68,000÷160=425 tons chord strain. In fact, the centre formula applied to a truss with but one chord, covers only a king-post truss of but two panels, in which two half panels rest directly on the piers, leaving only one-half of the gross load to be carried by the truss to the piers. In this 160-ft. span, 2 panels of 80 ft. do not form a practicable bridge, and intermediate supports must be provided. The centre formula only contemplates carrying $\frac{8}{16}$, while the Bollman carries $\frac{15}{16}$ of the gross load. These $\frac{7}{16}$ of difference can be supported by Fink's system of secondary triangles, or the whole 15 by Bollman's primary triangles, or by any form of trussing, and the units of horizontal work will still remain the same so long as the same panel data are used, or, in other words, so long as the same conditions of leverage are preserved by supporting the gross load at the same points and from the same depth.

Again, a truss is strictly a machine, at work carrying a load, and in it the law of equality between action and reaction is in full force! Tension must equal compression under an uniform load. The units of work or foot-tons in the hypothenuse of the right-angled triangles, into which all trusses are resolvable, must equal those in the base and altitude as inevitably as their foot-feet or squares, and their itemized account must balance. When compression exceeds tension in the chords, there is a corresponding excess of tension in the web system, and *vice versa.* To apply this to Shreve's Bollman truss, it is only necessary to multiply the tie strains given by him on page 328 by their respective tie lengths, giving 71,375 foot-tons of tension in the hypothenuse, from which deduct 15 tons × 15 ft. × 15 posts = 3375 foot-tons compression in the altitude, leaving 68,000 foot-tons compression in the base, which, divided by 160 ft., gives the same 425 tons chord strain we had before.

It seems clear, then, that the true strain in this 160-ft. span, is 425 tons instead of 320, and in view of the recent expiration of the Bollman patent, it is well to realize that the difference in strain is important in both a professional and business view. A chord proportioned by the Molesworth and Shreve analysis to carry 320 tons, at 4 tons per sq. in., with 5 for factor of safety, will contain 80 sectional inches. These 80 in. will really have to resist 425 tons of strain, or 5.3 tons per sq. in., at best a very unusual strain and one which cuts the factor of safety down to 3.8. The difference of 105 tons between the chord strains, at 4 tons per sq. in., represents 26 sectional inches, or say 90 lbs. of wrought iron per lineal foot of bridge, which, at 10 cents per pound erected, is $9 per foot, or about 10 per cent. of the ordinary contract price of the span in question. This sum is always decisive of fair competition between structures of equal merit, and is a larger per cent. than is ordinarily found on the cheerful side of the annual balance sheets of reputable contracting engineers.

THUNDERSTORMS AND STRUCTURES.

From "The Building News."

The Leipzic Academy of Sciences have appointed a commission to investigate the means adopted, and the results historically ascertained, with reference to the protection of buildings from the effects of lightning. They have been considering the dictum, proclaimed some years ago, of a civil engineer, who declared that "Science has every reason to dread the thunder-rods of Franklin; they attract destruction, and houses are safer without than with them." Now this is a theory which admits of being otherwise than scientifically treated. What do the records say? They assure us, that, in a majority of instances, the electricity of the cloud is drawn quietly down into the earth, so long as a good conductor is present; but whenever this becomes faulty, whenever it is interrupted, its destroying powers accumulate with terrible rapidity, and no other power known is so swift and fearful in its work of annihilation. The public, however, are very much in the dark with reference to this subject. It is, as a rule, more alarmed by the roar and rattle of thunder than it is by the flash of lightning, whereas the former is perfectly innocuous after the latter has passed. And the eccentric course followed by the electric fluid is constantly unappreciated. Thus Professor Henry tells us of an instance in which the lightning struck the top of a chimney, passed down inside the flue to a point opposite a mass of iron placed on the floor of the garret, where it pierced the chimney, breaking the plaster and burning the laths of the ceiling; then leaping, so to speak, into a bed chamber below, seizing hold of a copper wire, and travelling along it to another floor; next bursting through a dormer window, which fell, dashed to atoms, upon the pavement, and, finally, vanishing up a leaden gutter.

There was a man asleep in bed close by where it passed, and he never noticed the phenomenon. According to Sir William Snow Harris, who contradicts in this respect, the civil engineer we have referred to, a good conductor would have carried down the discharge without any danger or destruction whatever. It is known that on last Sunday evening balls of fire, and what is popularly called wildfire, exploded in the sky; and we have a chronicle indicating a similar wonder in the ruin wrought at S. Michael's Church, Blackrock, near Cork, in January, 1836. The spire was constructed of limestone, strengthened by iron bars and cramps within and without. The local record runs: "The fabric was seamed from the summit to the bottom by one gaping, jagged rent, 5 yards in width, and yet the wall might have been mistaken for that of a fortress." There was no protecting-rod. The Commission nominated at Leipsic undertakes to collect and compare the instances in which this apparatus has been employed with success, and where it has failed to answer its purpose. It can only decide upon historical evidence, of course; but an abundance of this is at hand. The ship Thisbe in 1816, unprovided with a conductor, was set on fire and nearly wrecked, in a thunderstorm; the electrical discharge struck her mainmast, swept her decks, flew from gun to gun, and reduced her fabric to a ruin. The Bayfield, also destitute of a conductor, was smitten, in 1845, from her deck to her hold, and totally destroyed. The Poland, five years earlier, was completely burnt out and blown up. On the other hand, the New York, an American packet, supposed to have been perfectly fitted, was struck as if by a broadside of cannon-balls; her bulwarks and spars ignited, her mast-head and cap took fire, her cabin furniture was shattered; all the watches worn by persons on board were stopped; the knives and forks in the steward's pantry were dangerous to touch, and yet the lightning-conductor rose 2 ft. above the top of the mainmast, and descended deep into the water. Turning to structures on land, we have the example of a house mentioned by Professor Henry. The electric fluid struck the summit of the chimney, it went down the flue, but was stopped by a block of iron on the floor of a garret; thence, however, in a second or two, it resumed its course, and exploded in a cellar, reappearing, in a most mysterious manner, from a cock-loft in the roof. We have testimony, moreover, to the effect that bell-wires are often perilously attractive to lightning. It is well ascertained, also, that the lines of the electric telegraph have frequently conveyed terrible shocks during the violence of a thunderstorm. They have on extraordinary occasions, actually evaporated beneath this irresistible influence. At Newbury, a steeple was hit, and the iron-work in it disappeared as though it had never existed. Faraday says he saw a dwelling in Westminster whence every trace of bell-wire, after a thunderstorm, had vanished. These are notes which it is important to remember, since they may lead to some reconsideration of a system upon which we rely too confidently, perhaps, for the safety of our habitations. A good authority, among others, remarks, after citing too many illustrations for us to quote: "In all the foregoing cases it will be observed that the metal chains, rods, and wires were not of sufficient size to convey away the charge of lightning; but being delayed in its progress, the astonishing heating power of the electric fluid had sufficient time to burn or fuse away the combustible metal. But, according to Sir W. S. Harris, quoted by the same authority (Mr. Tomlinson), "a copper rod of three-quarters of an inch in diameter would be sufficient to withstand the heating effect of any discharge of lightning whose destructive effect has ever been recorded." That, however, remains a question among the foremost men of science, and we are only tentatively putting it. Some buildings are fitted with two conductors of unequal proportions, which create the danger of the lightning passing from the smaller to the larger, penetrating through everything on the way. Even a nail in the floor has been known to divert its flight; it will go down against the smoke of a chimney; it will glance along the gilding of a picture-frame; it will hang about the hinges of a door, and this, in fact, as Rittenhouse asserts in the American Philosophical Operations, within 50 yards of a conductor, constructed and placed upon universally-approved principles. But the loss of human life, after all, through these ebullitions of nature, is comparatively slight. The famous case at Naples may be recollected. Lord Tilney was entertaining an assemblage of nearly 500 persons; the lightning attacked his palace. It melted, corroded, or blackened the gilding of the roof, the cornices, the ornaments of the chairs, and yet it traversed nine crowded rooms without injury to a single individual. However, although, as we have mentioned, the bolt will quit a small conductor for a larger one, it will occasionally, through some caprice of its nature, or, we should rather say, in obedience to some natural law not yet adequately understood, abandon the largest for a mere wire, or even be stopped in its descent by a gun-barrel. Some curious anecdotes in the chronicles of thunderstorms are related. That was a formidable storm which annihilated 85 ft. of the magnificent spire of S. Bride's, near Fleet street, erected by Sir Christopher Wren. The lightning struck an iron bar, which carried it safely down so far as itself extended; but then, the conductor ceasing, the masonry flew in all directions; several enormous blocks of stone were shivered into powder; others were almost melted; a few were blown to a distance, as if by an explosion. It would have been better in this instance had there been no conductor at all. The circumstances of S. Martin's Church, damaged in 1842, were almost precisely similar. The top of the vane-spindle was first struck; thence the lightning passed down the iron rod, without doing any injury, until the iron rod ended, and the fluid darted about from one iron-clamp strengthening the masonry to another. It burned the wood; it melted lead; it flashed upon the clock-dials, scorching them out of recognition; and it burst in the clock-room like a blast in a mine. Still, as we have said, the human mortality from lightning is not generally on a large scale, and might be very much reduced by precautions on the part of builders. Arago estimated that the number of deaths from this cause amounted in France to about 70 in the year; Bondin calculated that from 1835 to 1852, 1307 so perished; none in November, December, January, and February; but most in June and August. The lowest rate is assigned to Belgium, and the next to Sweden, the United States and England being about on a par. As a rule, however, these fatalities do not occur inside a structure of any kind. The peril, as experience shows, is less in a crowded town than in a village or in the open country, and, naturally, the more elevated structures are the most liable to be struck. Fuller, indeed, in his "Church History," asserts that there scarcely ever existed a great abbey in England which had not been, at one time or another, wholly or partially destroyed by lightning, and his citations, taken in comparison with the records of our own times, are certainly remarkable. In all cases it is the spire, the tower, and the dome which has been mutilated. As to ordinary habitations, all sorts of theories are in vogue on the subject of danger and safety. Some rely on thick glass in the windows, and some on register stoves; others recommend stone roofs instead of slate, and others tell timid people that they should live in a hollow. It is contended on this side that there should be the least possible admixture of metal in the combination of an inhabited structure; and on that, that all the bells beneath the roof should be kept continually ringing, just as, in obedience to an old superstition, cannon are fired at sea. The mass of evidence upon this topic points, however, to the one conclusion already suggested, that a good lightning-conductor is the solitary safeguard, but that, unless good, it is worse than none.

ECONOMY OF FUEL.

From "Engineering."

The "Revue Universelle des Mines" some little time ago published a series of valuable papers on the subject of the "Economization of Fuel," from the pen of M. Paul Charpentier, in which the author strongly insists upon the advantage of using fuel of every description in a gaseous state and under a constant pressure.

His arguments in support of this may be briefly stated as follows:

That combustion—employing the word in its ordinary industrial acceptation—may be what is termed perfect or complete, it is essential that the following conditions be satisfied:

1. The combustible and the supporter of combustion must be intimately intermixed.
2. These bodies must be in the same physical state, in which case alone the first-named condition is attainable.
3. They must be brought into contact at

the temperature best suited to their complete combustion.

4. With a like object a sufficient surface must be given to the flame.

5. The relative proportions of the combustible and the supporters of combustion must be exactly those requisite to complete combustion.

These conditions, M. Charpentier asserts, can be best satisfied by a system proposed by him, which is stated to be applicable to fireplaces of every class and description. The remarks in the "Revue" apply chiefly to the furnaces employed in industrial processes and for locomotive purposes.

To show the defects of the methods now in use, M. Charpentier institutes a comparison between the theoretical and the actual calorific power of ordinary coal.

Taking a coal of the following composition:

	kilog.
Pure carbon	65
Ash	5
Hygroscopic water	5
Tar	5
Illuminating gas	20
	100

he shows that according to the calculations of MM. Favre and Silbermann, and of M. Regnault, and asssuming the whole of the heat to be utilized, we have 8,038 calories per kilogramme as the calorific power of the coal. Each kilog. of this coal would, accordingly, evaporate 12.618 kilog. of steam at a pressure of 1 atmosphere. This is the calorific power in theory. In practice he asserts that the result is about 3 kilog. of steam for each kilog. of coal burned.

The causes of the waste of heat—and consequently of fuel—herein implied in the furnace of ordinary steam boilers he shows as follows:

1. Loss of heat occasioned by the pressure of atmospheric air in greater volume than is requisite to perfect combustion.
2. Loss of heat through the chimney.
3. Loss of heat by smoke.
3. Loss of heat by cinders.
5. Loss of heat in the evaporation of the 48 kilog. of hygroscopic water contained in every 100 kilog. of coal of the above description.
6. Loss of heat by radiation from the under surface of the fire-bars and other portions of the furnace.

In regard of the first, grouping the combustible constituents of the coal aforesaid, we have:

	kilog.
Carbon total	82.39
Hydrogen total	4.73
Sulphur total	0.188
	87.308

The total volume of oxygen requisite to convert the above into $C\,O^2$, $H\,O$, and $S\,O^2$, would be 257.7 kilog. Reducing this by the proportion of oxygen contained in the illuminating gas, we have still 256.28 kilog. of oxygen required, which supposes the presence of 1,114.30 kilog. of atmospheric air occupying a space of 861.7 cubic metres at a temperature of 0 deg. Cent.

But the presence of the fire-bars will not allow us to give the amount of air thus required in theory. The bars impede the free contact of the air with the fuel, and to feed the fire it is found necessary in practice to increase the size of the air passage and the velocity of the draught. Most writers recommend a constant supply of air of double the volume requisite in theory. And even then combustion is very incomplete. The temperature of the gaseous products and of the heated air on entering the chimney varies greatly; but in all cases the loss of heat thus occasioned is very considerable; in certain industrial processes, as puddling, etc., and in locomotives driven at express speed, the loss is enormous. As a very reduced average M. Charpentier assumes the waste of heat thus caused at 16 per cent. of the whole. Again, as regards the chimney itself. Some writers content themselves with the assertion that the chimney carries off in waste 25 per cent. of the heat produced by the fuel. And this assertion will admit of rigorous demonstration. Employing the foregoing data, and assuming the temperature of the gases on entering the chimney to be 500 deg. Cent., it can be proved that a loss of 18 per cent. is incurred, without taking account of the specific heat of the gases which are thus allowed unlimited expansion, or of the imperfect manner in which combustion is accomplished, or of the heat carried off by the carburets of oxygen and hydrogen contained in the smoke, whose capacities for heat far exceed that of atmospheric air.

It may, therefore, be concluded that it is of great importance to deprive the gaseous products of combustion of their heat before they enter the chimney, as well as to avoid the influx of atmospheric air in greater volume than is absolutely necessary to complete combustion.

Again, in the matter of smoke. The great smoke question, M. Charpentier observes, has formed for many years the theme of animated discussion. Many inventions have appeared, but none, as yet, have satisfactorily achieved the desired end. This has arisen from the fact that the inventors have confined themselves to a narrow, one-sided view of the matter. Many persons regard the subject—sanitary considerations apart—as of trifling moment; others have attached an exaggerated degree of importance to the consumption of the smoke, but without recognizing its bearings on the question of economy in fuel.

Five conditions have been enumerated above as essential to perfect combustion. Practically, very few of these conditions are satisfied by the arrangements now in use. The combustible—the coal—and the supporter of combustion—the oxygen in the air—cannot be brought into the requisite state of intermixture, as their physical states are dissimilar. Conditions 3 and 4 are satisfied at best by haphazard. Locomotive engines are particularly badly arranged in this respect; combustion in them is, accordingly, very incomplete, and their chimneys belch out clouds of the densest smoke.*

Now, the disadvantages of smoke are twofold: 1. It is insalubrious and a public nuisance. 2. It occasions a waste of fuel, and consequently of money, which in some cases is enormous, as few persons who have observed iron works, coke ovens, glass works, etc., pouring forth their sooty clouds, will be prepared to question.

But, smoke may be colorless, and yet carry off in waste the gaseous products of combustion to a very considerable extent. Many analyses have been attempted to determine the amount of unutilized gases contained in smoke. The mean of M. Debette's experiments showed a loss of 9 per cent. from this cause, but the first of these experiments indicated a loss of 24 per cent. Some experiments made in Alsace gave a mean loss of 15 per cent; Ebelmann only got 7 per cent; M. Ser, in a chimney at Thierry, got 40 per cent. These experiments, it should be said, were made with the furnaces of steam boilers. In many departments of manufacturing industry, the loss is far greater; and we shall be within the mark if we take the average under all circumstances at 20 per cent. The loss of heating power by the formation of cinders is often very great, and is also very variable. In locomotives, notwithstanding the narrow openings between the bars, it is of some consequence, as the cinders are not turned to useful account. In certain metallurgical processes, the loss is very great indeed; the fires are constantly stirred, and the imperfectly burned coals fall through into the ash-pit to increase the intense heat which radiates therefrom. In the experiments of MM. Tresca and Silbermann, at Cherbourg, the loss of heating power, owing to the formation of cinders, was found to be 25 per cent. of the total heat produced. M. Charpentier considers that we shall be well within the mark if we take the average at 15 per cent. The waste of heat occasioned by the evaporation of the water contained in the coal and of that produced in the combustion of the hydrogen may be taken as 3 per cent. of the whole. The losses through radiation and the formation of clinkers are smaller and very variable in their amounts.

The total waste of heating power, therefore, stands thus:

	per cent.
Loss of heat occasioned by the presence of an excess of atmospheric air	16
ditto through the chimney	18
ditto by smoke	20
ditto by cinders	15
ditto by evaporation of water in the coal	3.6
ditto by radiation, etc	variable
	72.6

Say, 73 per cent. as the waste of an ordinary open furnace with natural draught. This is only a general average. In very many cases it is far exceeded.

Applying the foregoing to steam furnaces, we find that in place of 12 kilogrammes, the theoretical amount, only 3.3 kilogrammes of steam are evaporated by each kilogramme of coal; this, be it observed, hardly conveys a correct notion of the actual results, as a good deal of water is often carried off by the steam, thus increasing the weight of the latter. So much for the defects of the arrangements now in use. The waste of fuel thus occasioned, M. Charpentier proposes to reduce by suppressing the chimney altogether, and by consuming the fuel in a gaseous state and under a constant pressure, so that the variations in volume—and consequently in capacity for heat—which are now experienced by the gaseous products of combustion, may be avoided. He notices

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* M. Charpentier's experience with locomotives appears to have been of an unusually unsatisfactory kind.—Ed. E.

the various projects for economizing fuel, which have hitherto appeared, under four heads:

1. Revolving grates.
2. Supplementary appliances for the introduction of hot or cold air.
3. So-called "smoke-consuming furnaces," in which steam is injected upon the flame, upon the fuel, or into the chimney.
4. "Gas-stoves," so called.

The more or less complicated arrangements under the first head have been pretty generally abandoned. Those under the second are very nearly useless. It is not, generally speaking, that the air is present in insufficient volume—on the contrary, it is usually in excess—but that it is impossible to give it the requisite degree of intermixture with the incandescent fuel. The additional volume of air introduced tends rather to exaggerate than to diminish the loss of heating power. Those under the third heading are better adapted to the end sought, but the injected steam absorbs heat in decomposing, it increases the loss through the chimney, and costs dear for results that are practically small. The "Thierry" furnace, which is about the best, effects a saving of 10 per cent., but, it is admitted in the inventor's prospectus, that this saving is achieved at an expenditure of 8 per cent. of steam.

Lastly, we have the so-called "gas stoves." The principle of a preliminary reduction to a gaseous state of the fuel is an old one. Its first practical application in France was by MM. Laurens and Ebelmann. Since the researches of the latter, it may be said that no advance has been made, although the question has reappeared in sundry forms.

The most successful recent attempt has been that of M. Siemens. The loss of heat in the case of this gentleman's apparatus is estimated by M. Charpentier at 50 per cent., showing a saving of 20 per cent. over the arrangements in ordinary use.

After a lengthy discussion of the theoretical principles of heating with gas under a constant pressure, M. Charpentier proceeds to describe an apparatus, by which he thinks it is demonstrable that enormous advantages might be realized. He proposes to adapt it to fireplaces of every class. It consists of three distinct parts: 1. A gas generator or gazogene, in which the fuel is brought into a gaseous state. 2. A burner, in which the gas produced in the gazogene is burned. 3. An hydraulic regenerator. The gazogene is of ordinary design, and is supplied with condensed air by some sort of fanner; steam is also injected on the incandescent fuel.

The burner is in the form of a pipe placed in any position required, and connected by a valve with the gazogene. It is so arranged that the burning gases are surrounded by air, which impinges on them at an angle, that can be varied according to circumstances, and to the length of flame required.

The hydraulic regenerator receives from the burner the gaseous *residue* of combustion, and secures the following results:

1. The almost perfect utilization of the sensible heat carried off by these gases, which sensible heat has hitherto been employed only in maintaining the wasteful draught of the chimney. It may be observed, that the necessity of having a draught to assist in the reduction of the fuel is obviated by the employment of condensed air, by which, it is calculated, a saving of 25 per cent. will be effected.

2. The utilization of the heat rendered latent by the evaporation of the water existing in the fuel, and of the water produced by the combustion of the hydrogen in the latter, which latent heat is transformed into sensible heat available for useful application.

3. The economization of the heat hitherto wasted by the unlimited expansion of the gases. The maintenance of a constant pressure prevents any portion of it becoming latent, and thus not practically available.

4. It assists in securing complete consumption of smoke.

5. The water in the regenerator being almost always employed to feed the steam boilers, and being at a temperature of about 100 deg. Cent., the excess of carbonic acid which it contains, becomes quickly separated therefrom, and the calcareous matters held by it in solution in virtue of such excess are deposited in the regenerator, thus securing the boiler against incrustation.

The advantages claimed for his system by M. Charpentier are the following:

1. It may be used with any sort of fuel.

2. It will give greater durability to metallurgical furnaces by getting rid of the excess of oxygen, the chief cause of destructive oxidization.

3. The nature and intensity of the flame may be regulated at will.

4. It may fairly be expected to give not only increased economy but improved results, in iron and steel manufacture.

5. In marine boilers the saving in fuel effected will enable a smaller supply to be carried, others give increased capacity for accommodation or stowage.

6. It gives a higher temperature than any method yet devised.

7. The boilers are saved from incrustation, and the chances of an explosion are thus reduced.

8. The suppression of the smoke is complete. In addition to these direct and indirect advantages we find a total absence of cinders.

Appended to M. Charpentier's memoir is a *procès-verbal* of some experiments made with his apparatus on the Orleans and Rouen Railway, in the month of September, 1872. The results are stated to have been very satisfactory. The saving of fuel in the locomotive employed amounted to 47 per cent., and in one case to 66 per cent. These results, however, appear to us to require confirmation, and M. Charpentier seems throughout his memoir to have exaggerated losses, and to have considerably underrated the results obtainable by other plans than his own.

CLAMOND'S INDUSTRIAL GENERATOR OF ELECTRICITY.

Translated from "Les Mondes."

The easy and economical production of electricity of constant quantity and tension, is still an unsolved problem. Hitherto the attention of those who have attempted its solution has been almost exclusively directed to magneto-electric machines, *i. e.*, those which transform mechanical work into electricity. A great number of these machines have been constructed; among these is that of Gramme, which gives a current in one direction only, a machine which is but a practical realization of the apparatus described by Faraday. All these machines have a capital defect; not one of them furnishes an absolutely continuous current. Besides, their use is limited and very much restrained, for they require a motor of more or less power, which can yield only a small fraction of the theoretic work due to the combustion of charcoal. Add to this that not only the magneto-electric machine, but also the motor, are of high price, and require the continual service of at least one extra workman, and we see that the question is still an open one, and that inventors need not look in this direction for the realization of the industrial production of electricity.

The same may be said of hydro-electric piles. True, these furnish a continuous current, though not constant, but they are very expensive to run.

Since Seebeck's discovery there have been many attempts to construct thermo-electric piles of sufficient tension and quantity to displace the ordinary piles.

Messrs. Edmond Becquerel and Marcus have constructed thermo-electric piles, giving remarkable results, when compared with those attained by Seebeck. Those of Becquerel, composed of bars of sulphuret of copper, gave a current of strong tension but small quantity; those of Marcus produced a considerable quantity of electricity. More recently MM. Mure and Clamond, having observed and studied the thermo-electric qualities of galena, constructed with this ore thermo-electric generators of great and remarkable power. In the disposition and use of the elements, the pile was converted into a furnace, employing coke or gas in an economical way. But at first the result desired was not attained. The defect was that which is common to all thermo-electric piles previously inverted, viz., the rapid weakening of the current, especially when employed for actual and continuous work. After these fruitless essays it became an admitted opinion that such piles have no durability; that after a few hours, or, at most, days of action, the interior resistance increases and the current diminishes, so as to become almost null. It therefore became necessary to remove this fatal defect.

Availing himself of the knowledge gained by repeated experiment, Clamond has at last succeeded in solving the problem. He has constructed an apparatus which leaves nothing to desire, either in respect to performance or durability.

Our colleague, F. Michel, has made experiments upon this pile during the last ten months. From these numerous and carefully-conducted experiments the conclusion is drawn, that the electro-motive force and the resistance of couples do not experience the least variation under the action of heat at a constant temperature. More than this, successive heatings and coolings do not alter the qualities of the elements, affecting neither electro-motive force nor resistance. This result has never before been attained.

In the old galena piles Michel had observed that the passage of the electric current caused decomposition of the ore, and consequent variation in structure, interior resistance and electro-motive force; that the decomposition showed its progress by striæ, so that after a time unequal dilatations ensued, followed by splitting of the bars. With Clamond's new elements, all these defects are absolutely removed, the chemical and molecular condition remains exactly the same for an indefinite period.

While the hydro-electric pile has remained of the type created by Daniell and Grove, and the magneto-electric machines have given unsatisfactory results in spite of ingenious combinations, a new electricity has grown up in a modest and quiet way. To-day thermo-electricity takes its place as a new element in aid of science and industry.

Clamond's apparatus serves every purpose. It furnishes for laboratories a convenient generator of electricity, requiring but a lamp to keep it in action. Of larger dimensions, heated by coke, it generates electricity with a constancy and an abundance of supply never before realized.

HYDRAULIC MORTAR IN FRANCE.

From "The Architect."

The particulars, derived from official documents, of the manufacture of hydraulic mortars for the production ef concrete intended to be used under water, as practised in the Government works in the north of France, have been published.

These mortars are generally composed of the hydraulic lime of Tournay, coal cinders, and Dutch strass, in powder. These substances yield a rich mortar, which rapidly acquires good power of resistance. The concrete, when mixed with small materials, is easily laid under water, has little waste, and forms excellent foundations.

The only inconvenience attributed to this kind of mortar is the complication of its manufacture which requires four perfectly distinct operations, demanding, if not special workmen, at least men of a certain amount of intelligence. These operations are:—(1.) The sifting of the lime in powder. (2.) The addition of the proper quantity of other materials. (3.) The mixing them together in the dry state and afterwards adding the proper quantity of water, and lastly, the mixing up of the mortar itself.

The work is carried on night and day, and, in one instance, employs in the twenty four hours 28 men and 6 horses; yet, with this considerable force, only $1\frac{1}{2}$ tons of mortar per hour are produced, or 36 tons in the twenty-four hours, or about the quantity necessary for the formation of 72 cubic metres of concrete per day.

The Minister of Public Works has sent to the Vienna Exhibition the model of a machine, on scale of 0.10, which, with the aid of a steam motor, performs all the operations mentioned above. This consists consequently of four distinct parts, the bolter, distributor, dry mixer, and the crusher and maker. The bolter is mounted above the distributor, and is much like the ordinary flour-bolting machine. The lime, previously reduced to powder, is carried by two men in wooden boxes, each of which holds 22 gallons; it is emptied into the upper part of the bolter, and the lumps, etc., fall out at the opposite end into a truck. The bolter is composed of iron plate pierced with holes of rather more than a millimetre in diameter (rather less than $\frac{1}{20}$ of an English inch), and the sifted lime falls into a chamber perfectly tight, glazed traps allowing the interior to be seen, and, when necessary, visited. On a level with the floor of this chamber is the distributor, which is composed of three parts, each $4\frac{3}{8}$ in. in height, but varying in size in proportion to the quantities of the several materials employed.

The vessel which measures the quantity of lime is placed under the chamber, and the other two parts beneath receptacles provided for the strass and cinders. The capacity of these three measures is for each nearly a metre. They are connected by their upper edges to the same supporting plank or table. Beneath these measures turns an iron disc about $\frac{1}{4}$ in. in thickness, connected with a vertical arbor. A large opening is made in this disc, so that at every revolution it alternately opens and closes the lower part of each of the measures. Beneath the first set of these is another of exactly the same form and capacity, and with the vertical arbor already mentioned is a second disc which closes the bottoms of the lower set of measures, the two sets being only separated by the thickness of the upper disc. The openings in the two discs are not coincident, so that when one of the upper measures is open, the lower corresponding one is always closed, and *vice versa*. The discs are set in motion by a spur-toothed wheel, and can be thrown out of gear at will. The action of the measures is self-evident. When one of the upper set is full the disc below it opens and allows the contents to fall into the corresponding receptacle below, and as the disc proceeds on its course, the lower measure is closed above and opened beneath, when its contents fall into the mixer. The disc makes 17 revolutions a minute, so that each of the three measures is filled and emptied as many times in the same period.

The mixer, which is placed beneath the distributor, consists of a fixed cast-iron cylinder, with an opening above at one end, and a horizontal arbor passing through it longitudinally, which makes 31 revolutions per minute, and which is furnished with palettes set at uniform distances around it, and at an angle of about 45 deg. to the axis. These palettes reach nearly to the circumference of the cylinder, and while mixing the ingredients, cause the whole to pass towards the further end of the cylinder. Towards the middle of the cylinder is a trap by means of which the progress within may be observed, and at the same point two jets of water are introduced from a cistern placed about 6 ft. above.

The mortar falls, perfectly mixed, from the cylinder to a mill beneath, which consists of 3 rollers of unequal diameter, all geared with each other. Looking only at the mortar as it issues from the mixing cylinder, the mill would appear to be completely superfluous, but it has been found that mortar made by mere mixing is of much less density than that which has passed through a mill of any kind afterwards; hence the addition of the latter to the machinery in question. The whole of the apparatus is simple, and easily taken to pieces and repaired, or the parts exchanged.

The engine used to drive the machinery is of 6-horse power; its axis makes 85 revolutions a minute, and drives, on one hand, the bolter, and, on the other, an arbor fixed on the frame of the machine itself, which communicates motion to the distributor by means of a driving band, and to the mixer and mill by means of gearing.

PROBABLE CAUSE OF THE DESTRUCTION OF BOILER TUBES.

By J. H. KIDDER, M. D., U S. Navy.

Written for Van Nostrand's Magazine.

It is a fact familiar to all practical engineers that the tubes of marine boilers, attached to condensing engines, whether they be supplied with fresh or salt water, "wear out" sooner or later, and have to be renewed. The term "wear" is, however, scarcely used with propriety in this connection, since when thus damaged boiler tubes do not present an appearance of uniform erosion, such as would result from "wear," but are riddled with holes and marked by pits or depressions. To the eye of a medical man these holes and pits bear a remarkable resemblance to ulcerations of the skin, the destruction of metal being greatest in the centre, and irregularly graduated thence toward the edges, so that each pit is of a funnel shape, its sloping sides presenting a *stratified* appearance, as if the rodent action had been irregular and intermittent. The holes and pits occur always upon that surface of the tubes which is immersed in the water contained in the boiler. So far as I am aware, the cause of this kind of destruction of boiler tubes has not yet been satisfactorily explained, although there is an opinion current among practical engineers that the presence of copper has something do with it.

By the kindness of Mr. W. C. Selden, of

this city, I was permitted to visit the steamer Clyde, of the Galveston line, on the 31st of July last, and to witness the operation of a filter which he had devised for the purpose of preventing this injury to boiler tubes, and which had up to that time proved successful. A long iron box, fitted with a steam-tight cover, was introduced between the condenser of the Clyde and her boilers. This box was divided into compartments by diaphragms of felting, pervious to water, and the compartments themselves filled with coke. By means of this simple contrivance Mr. Selden had collected a considerable quantity of a greasy, earthy substance, showing patches of a brilliant cantharidal green color, but generally of a brownish black. This substance he believed to be the real cause of the holes in boiler tubes above referred to, and, certainly, this being removed, the tubes of the Clyde had ceased to "wear out." At Hecker's flour mills also, when fresh water is used, the boiler tubes had required constant renewal, as in cases where salt water had been used, until the introduction of the filter, with the same beneficial result thereafter.

I had the opportunity of examining a portion of this substance, with the result hereinafter presented. The examination was necessarily incomplete, and can have no claim to chemical accuracy. Its results are presented in the hope of attracting the attention of practical chemists to what seems to be an important subject.

The specimen examined came from the condenser at Hecker's flour mills, and consisted of irregular, greasy lumps of mixed brown, black, and cantharidal green color.

(*a.*) A quantity of the mass was warmed, treated with alcohol (90 per cent.), and filtered, washing freely with alcohol. A green solution passed through the filter, becoming, on the addition of dilute sulphuric acid, reddish brown. On adding water, an oily stratum (oleic acid) rose to the surface of the liquid, somewhat disallowed by the sulphuric acid, which was too strong.

(*b.*) The residue on the felter was washed with ether, bringing down a little more greenish solution and some free oil. The substance remaining on the filter is dark brown, friable, and insoluble in water, alcohol, and ether. It is found to consist largely of carbon, with traces of iron, copper, and zinc.

(*c.*) A strong solution of chemically pure sulphate of copper was prepared and added to a filtered solution of pure oleate of potassa (prepared from olive oil and liquor potassa) in alcohol. The resulting oleate of copper was dissolved in hot alcohol and filtered; on evaporating to dryness, a green pulverulent mass resulted, which became tenacious and of darker color when heated.

(*d.*) In the same way an artificial oleate of iron was prepared for comparison; a thick, dirty, green mass, only partially soluble in alcohol.

(*e.*) A fresh portion of the green substance dissolved out of the original specimen by hot alcohol was heated to boiling, at first in alcohol, afterwards in water, immersing a clean knife blade in the mixture the while. A minute but quite perceptible trace of metallic copper was deposited upon the iron.

(*f.*) A small quantity of the alcoholic solution obtained by "*a*" and "*e*" from the original substance was decomposed by a small quantity of dilute sulphuric acid as in exp. "*a.*" An oily stratum rose to the surface. Connecting the subnatant fluid with a two-cell Smee's battery, and immersing a clean iron spatula in connection with the negative pole, an instantaneous deposition of metallic copper upon the iron occurred.

(*g.*) Replaced "*f*" by a solution of pure oleate of copper, made artificially by "*c.*" Upon adding dilute sulphuric acid, a separation of oleic acid occurred as under "*f*," but in much less quantity, in proportion to the amount of oleate of copper used, than appeared by that experiment. On immersing the spatula in connection with the battery, as before, copper was plentifully deposited, scaling off from time to time, particularly over spots of rust, and floating free in the liquid. When the deposition of copper had become less active the liquid was tried by ferri-cyanide of potassium, indicating the presence of iron in large quantity, as protoxide. Since this last solution was made with only chemically pure sulphate of copper, olive oil, and liquor potassa, the presence of iron could only be accounted for by supposing an interchange between the copper of the solution and the iron of the spatula. By adding a small quantity of melted wax to "*f*," oleic acid was separated in a solid cake, and, as has been seen, metallic copper was obtained from the fluid portion by the aid of the galvanic current, the remaining solution showing the presence of iron, derived from the spatula, used as negative pole.

These experiments seem to have established the presence, in the substance collected by Mr. Selden's filter, of an oleate of copper containing a larger proportion of oleic acid than the artificially prepared salt (*vid.* "*g*"). By exp. "*e*" it would also appear that under the influence of heat and in presence of iron an interchange will occur between the metals, oleate of iron being formed and metallic copper set free, this interchange being much more rapid when the chemical action is intensified by galvanism. Besides oleate of copper the substance examined contains free oil, a large quantity of carbonaceous matter, and traces of copper, iron, and zinc. The experiments have been detailed, at the risk of tediousness, in order that any error that may have been committed may be more easily traced.

The presence of oleate of copper may be accounted for by the decomposition of the olive oil used in lubricating the piston into oleic acid and glycerine. Since a heat of between 400 deg. and 500 deg. Fahr. has been found in practice necessary to this decomposition (Watt's Dict'y Chemistry, Vol. II. p. 886), it is manifest that the steam from the boiler can never be hot enough for this purpose. But it is easy to believe that along the line of friction between the piston and sides of the cylinder an exceedingly high temperature is momentarily produced at each point of contact. The quantity of this heat of friction is trifling, but its intensity is very high, quite sufficient to decompose the thin film of oil interposed between the piston and the sides of the cylinder. In the process for the manufacture of glycerine by the injection of steam (Watt's, *loc. cit.*), it is found that glycerine is easily separated from oleic acid, owing to the fact that it is carried along much faster and farther by the escaping steam than is the latter. A small portion of oil, then, having become decomposed into oleic acid and glycerine, the latter passes through the condenser first and harmlessly, and the former somewhat later. In the condenser the brass tubes are exposed to the powerful comminuting impact of steam at a high temperature and pressure, and their substance is thus finely divided and placed under the most favorable circumstances for union with the free oleic acid which the steam brings with it. Oleate of copper is then formed (as I suppose) in the condenser, and appears as bright-green greasy masses, which are carried from the condenser into the boiler.

Here, being quite insoluble in water, these masses accumulate (in accordance with a familiar law) in those parts of the boiler which are least disturbed by currents; and it is precisely in those parts (at the ends of the tubes) that the most corrosion is found. Settling upon one of the iron boiler tubes a mass of oleate of copper adheres thereto, and, favored by the conditions of high temperature and pressure, the deposition of copper and absorption of iron begins. If the oleate of copper were soluble in the water of the boiler, the erosion of the tubes would be uniform over their entire surface. Being insoluble, however, its action is confined to the surface of contact, hence the small holes characteristic of this kind of injury. Since, as shown by exp. "*g*," copper thus deposited will remain adherent only to perfectly smooth iron, and since boiler tubes are never in this condition, the copper is probably removed by the action of water as fast as deposited, leaving constantly a fresh iron surface for further action. Whether the action which takes place in the boiler be galvanic or chemical is uncertain, if indeed there be any essential difference between these two modes of action, other than a difference of degree.

Mr. Selden has been in the habit of adding a quantity of free soda to the contents of his filter, having observed an acid reaction in the water which leaves the condenser. Since, however, the oleates of the metals, oleic acid, and free fat are alike insoluble in water, the advantage of this proceeding would seem to be at least questionable. For if free oil be present the soda added will form a soluble oleate (soap) which may pass through the filter, and is readily decomposable by any soluble metallic salt which it may meet, forming the very oleates which it is the object of the filter to exclude. If free oleic acid be present it is rendered soluble by the caustic alkalies, and its power for mischief thereby increased; while the metallic oleates, although not decomposable by soda, may, if acid salts (as seems probable by "*f*" & "*g*") give up to it a portion of their oleic acid which would otherwise be stopped by the filter. Moreover, since sea-water contains an abundance of calcic and magnesian salts, any free oil or oleic acid which might pass over into the boiler would be at once converted into an insoluble and harmless lime or magnesian soap in a marine boiler. And it is by no means certain that, even if not so decomposed, they possess any hurtful power when uncombined with a metallic base. Lime is the only alkali which is theoretically likely to be of advantage, and that only when used in connection with a fresh-water boiler.

At Hecker's mills the condensed water after leaving the filter is treated with atmospheric air, forced through it from below. The resulting water is perfectly free from taste or odor and quite potable. It seems possible that the hitherto insuperable difficulties in the way of freeing condensed water on shipboard from a certain unpleasant empyreumatic odor and taste may be overcome by a similar treatment.

NAVAL LABORATORY,
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THE IRON-CLAD QUESTION.

Translated from Rivista Marittima (Italian), for the Junior Naval Association.

The question of the future of iron-clads is certainly a most complicated one; dread of allowing ourselves to be surpassed by other nations, and that of spending many millions upon ships of doubtful success, produce great uncertainty. In England, where the naval question is one of vital interest, where there are glorious traditions to continue and a supremacy to maintain, and where, especially, the country recognizes the importance of the navy, and is prepared to make serious sacrifices to keep it in the first rank,—in England, naturally, the question has been discussed at greater length and more advantageously than elsewhere; the press has studied it with some real acquaintance with the case, and its criticisms, though often unjust, have not been dictated by some fancy for casting reproaches at an important institution, with the sole object of creating opposition or of amusing the public, but were intended to throw light upon useful ideas, and to promote the introduction of additional improvements; so that to study the actual state of affairs, we can have no better guidance than that of the English journals of most authority on the subject, like the "Engineer" and "Engineering" and others, from which the following observations have been extracted, in great part word for word.

With the loss of the Captain practically ended one of the most important disputes which have ever arisen in maritime affairs; for many years the relative advantages and disadvantages of ships of low freeboard (*piccolo bersaglio*), like the Captain, and of those with higher sides, of which the Devastation is the type, had been discussed with ardor and ability. Men of authority were divided into two camps, and the discussion sometimes became so violent as almost to degenerate into personal attacks; scientific men of other countries took part in it; never had any subject been so generally considered as that of the construction of ships of war. In the end, the views of Captain Coles were painfully condemned by the catastrophe which crushed the defenders of the Monitor system. In the meantime, the fleet had been to a great extent re-constructed, and there was a truce to discussion, when a letter from Mr. Reed, published in the "Times," recalled the attention of the public, by awakening a general panic by means of certain obscure phrases, in which he seemed to allude to inventions doubly superior to his own constructions of two years before, and the consternation of the public was as great as though the English fleet had been sunk, or driven from the seas by the Russians or by the Extra-Europeans. Nor were there wanting anonymous writers, who asserted that Mr. Reed's ships could neither steam, nor sail, nor fight, not even float. Meanwhile, the attention of the public was directed anew to the affairs of the navy; new discussions were brought on; and there were not only two great camps, but even a dozen parties, all of which pretended to be able to give to the world the war ship of the future. In these controversies it is highly probable that considerations of real importance would be lost sight of, if an attempt be not made to guide opinion into a path advantageous to the nation. There is no better way of doing so than by making a brief investigation into the force of the navy, and by examining rapidly what progress may be hoped for in every class of vessel; and above all, it is well to consider, what are the requirements of the State, and to what extent they are met by the means at present in its posession. To England are necessary three great classes, or types of ships:—The first is that of large vessels with heavy armor plating, charged with all the duties which formerly fell to the lot of the ships-of-the-line of from 70 to 120 guns; the second is that of swift, unplated ships, heavily armed, destined to maintain the police of the seas; whilst the third and last consists of ships which may properly be called floating fortresses, intended solely for the defence of the coasts, or rather of the ports. Let us begin with this last class, to which belong the circular iron-clads mentioned by Mr. Reed. Such ships should never go out of sight of land, or rather should but rarely go outside a harbor; they would not have to carry more than twenty-four hours' coal, that is a couple of hundred tons. It would not be difficult to make them invulnerable to the efforts of the most formidable guns which will ever be brought against them, and not having to bear a heavy weight of equipment—coal, water, and provisions—they might carry plating of 24 in., and two or even four guns of the heaviest calibre. Their work would be limited to the destruction of an enemy's fleet which might dare to approach the great seaports; they would be, as it were, house-dogs; they would not require great speed, because it would not be their duty to pursue the enemy. No naval architect would find any difficulty in the construction of similar ships; for, although he would have to make them large enough to carry armor-plating and guns, he would not have to think of coal, stores, powerful machinery, rolling, or any of those things which are the despair of the constructor.

The construction of swift unarmored ships is not by any means a difficult problem: the coal would take the place of the armor-plating; and though serious consideration of their stability and power of keeping the sea for long periods would be necessary, still these are difficulties which it may be asserted can be surmounted successfully. There are not wanting opponents, who declare that these swift unarmored ships would be useless because they might be easily destroyed by iron-clads; but even then their case would only be that of the frigates in the days of the line-of-battle ships; the former were able to avoid their more powerful antagonists, and were useful and popular ships, so the modern unarmored frigates or corvettes would fight with each other and leave the iron-clads alone; whilst these latter would find a by no means agreeable opponent in a ship running 17 knots, and carrying a couple of 25-ton guns, and would have to burn a good deal of powder to keep her at a distance. It may therefore be held to be necessary to have a good number of these light vessels, good under sail and especially so under steam, to protect the national commerce and destroy that of the enemy.

It now remains to consider the class of heavy iron-clads which would form the fleet-of-the-line; but here we encounter many difficulties. First of all, it must be admitted that these iron-clads are the true strength of the naval power of the country; they are what were the huge liners of Nelson, and in them fighting qualities should have precedence over all others. It was not, assuredly, the swift frigates, nor the saucy corvettes, that achieved the maritime supremacy of England; a lighter fleet might leave astern these heavy vessels, but it would end in destruction under their fire. As it then was, so will it be hereafter: the ships that can best maintain the line of battle, and, by keeping together, best resist the most formidable assaults. will be master of the sea, and a greater speed or better qualities as cruisers will not, in the long run, serve its adversaries. Now, as then, the true strength of the English fleet is in the heavy ships-of-the-line; to them belongs the duty of guarding the coast from the attacks of any hostile fleet whatsoever, and of pursuing it, if need be, wherever it can go to reduce it to extremities; they ought, moreover, to be fit for distant service and able to proceed to the South Atlantic, to India, to the Pacific, wherever indeed great actions may be fought, resting on a local base of operations. This established, let us see what should be the qualities of such ships. It being probable that in future naval actions, as in those of former days, ships will encounter each other at close quarters, and that a ship will often have to sustain a concentrated fire, un-sinkableness (*insommergibilita*), or the possibility of resisting shocks of all kinds, obtained either by means of armor-plating, or in other ways, becomes a condition of the first importance. And when also, as is possible, the beak or the torpedo may supersede the gun, the ideal ship-of-the-line should always retain the same defensive power, so as to be able to use in action all the means of offence with which it is supplied, in spite of the enemy's guns, which will certainly reserve themselves to keep, if possible, at a distance both rams and torpedoes; so that not only will the thickest plating be always necessary, but also and even yet the most powerful guns, though but of secondary importance. To speed is assigned less importance because it will be necessary to sacrifice to it some fighting qualities, though one or two particularly fast ships-of-the-line, like the Fury, may prove most useful, if it is always safe to approach an enemy short of coal, or in a position which cannot be avoided; and at the moment of action the fastest engines will go slower, since passing with great rapidity close to the enemy cannot lead to important results. Great importance, however, will be given to facility of manœuvring and to the powers of the ship as a ram, since it is probable that on the ram will depend half, if not the whole result of a naval action. With respect to locomotion, English ships-of-the-line will always have to be so fitted as to go wherever Nelson went, relying upon their engines only, allowance being made for facilities of replenishing their fuel and of the most rapid actual means of communication, which would certainly in future render a pursuit much shorter than that in which Nelson chased Villeneuve.

For the defence and maintenance of order in the colonies, ships without masts may be always made use of, or those furnished temporarily with a jury rig, it being always possible to have a local supply of coal. So that for ships-of-the-line, masts could be entirely abolished, it being acknowledged that their absence is an important element in their fighting qualities. There are not wanting, however, opponents of this abolition of masts, and not long ago a writer in the "Daily News" took advantage of the fact of an accident having happened to a supplementary portion of the Devastation's machinery during her trial, to draw a lamentable picture of that huge monster helplessly abandoned on the sea, and waiting for a friendly tug; but trial trips serve especially to point out the defects of the machinery; and in reality, at the present day, both engines and boilers—except in fatal cases—exhibit sufficient guarantees to trust to them alone for the working of the vessel. As to sea-going qualities, the ships-of-the-line should be able to keep the sea in any weather; but that need not include the necessity of being able to steam swiftly against a heavy sea, particularly when it is thought proper to adopt low extremities for the devolopment of the turret system, for a ship can be a good sea-boat without this superfluous quality.

Having laid down these conditions, the English journals inquire how far their fleet complies with them. This fleet is composed of the Devastation and Thunderer already launched, and of the Fury as yet unfinished; all are of the same type except that the Fury has greater defensive powers and is faster: she promises to be one of the swiftest ships of war in existence, and thus will be exempt from any difficulty that may arise from accepting slowness as an essential characteristic of line-of-battle ships. But it is only by comparison that the Devastation can be regarded as slow; at the measured mile she ultimately attained a speed of about 13.9 knots, a most excellent result if the relation between the nominal power and her displacement and the fulness of her lines be taken into account. As to facility of manœuvring and proceeding under steam—from long use—the new designs appear perfect; the cruise of Nelson to the West Indies and back is quite within the power of these ships, even without replenishing their coal supply. As to their floating qualities and armament they are quite up to the level of the times, being therein superior to any ships yet launched, and only threatened with a rival of doubtful superiority (at best but equal to the Fury), the Rusian ship Peter the Great—still on the stocks. The sea-going qualities of the ship remain for consideration, but upon them nothing positive can be said before the final trials; still, the trials made up to this time, of the Devastation, promise, even in this respect, very satisfactory results.

To this powerful group of three ships must be added the two rams, Rupert and Hostpur, which will of a surety prove useful auxiliaries in a general action: both are protected at the water-line by a plated belt 11 in. in thickness, which is extended only 18 in. above water, at which height there is a deck protected by thick plating, capable of resisting plunging fire from powerful guns; the sides rise above the deck un-armored, but within there is an armor-plated casemate (*ridotto*).

In the Hotspur, a ship of 2,600 tons, the casemate is elevated above the upper deck and forms a fixed turret with several parts, in which there is a 25-ton gun mounted on a platform, protected by armor of only 8 in. In the Rupert, which is of 3,160 tons, the casemate carries armor of 12 in., and terminates in a revolving turret, plated like that of the Devastation and armed with two 18-ton guns. So that these ships are not unworthy of being placed in the line of battle with the Devastation, but the power of their artillery, especially that of the Hostpur, is small, since they are protected by weak plating, which, however, is of minor importance as they are specially designed for ramming. They are not intended to keep the sea for long periods, for they have only the usual supply of fuel. The speed of the Rupert is 14 knots; that of the Hostpur is between 12 and 13, and will probably be adopted in naval operations near the home coasts. Besides these five ships, the Glatton may well take part in a battle fought in home waters, her armor being as thick as that of the Devastation, although she has but one turret and two 25-ton guns, instead of four of 35-tons; her speed is 12 knots and her coal supply moderate. But even excluding the Hostpur and Glatton, the Thunderer, the Devastation, the Fury, and the Rupert, constitute a fleet of extraordinary individual power (though small in number), fit to go wherever the best ship of the line may be required. It is natural that there should be a desire to have, beyond everything, this number increased, in view of what other powers may do or are beginning to do; but the fleet at present existing, small though it be, is not at present in danger of being surpassed. Before making fresh constructions it is necessary to make careful trials at sea with the Devastation and the Thunderer, and to study well in what way the powers of guns and armor may be still increased, without exceeding the moderate dimensions of present ships. Mr. Reed and other eminent persons (amongst them Admiral Sir Spencer Robinson) cry out against the Government, which they accuse of having hesitated in the path of progress; but even though England should not construct another ship for two years she would still remain at the head of naval powers; these two years in advance, which compensate for the immense sums spent on the navy, authorize the nation to rest in its course to take breath whilst other powers still crowd sail to catch up with, or surpass it. Mr. Reed asserts that his best designs are already antiquated; but what kind of ships then should be constructed? To this question there is no answer. With the increase in the thickness of armor the dimensions and the cost of the ship of necessity increase. As for armor, the maximum has, perhaps, been already reached, and there exist guns capable of penetrating the Devastation at a greater distance than 1,000 yards. Ships designed for the defence of ports may be protected by armor almost *ad libitum*; but it is not the case with ships destined to go to sea. It is difficult to imagine a ship that can carry more than a long strip of plating capable of resisting 35-ton guns; and the limits of artillery have not yet been reached.

There, therefore, arises a doubt as to whether or no armor of 12 in., which can be pierced, is worthy of the sacrifices that must be made, in order to have ships capable of carrying it; but if it be preferable to have no armor, rather than to have it of but 6 or 7 in., which can easily be penetrated by projectiles, the same cannot be asserted of a thickness of 12 in. Moreover, there are but few guns afloat which can penetrate it; and when we take into consideration the remark of Captain Osborn, published in the "Times," that that which is most to be dreaded in battle, is the bursting of a shell between decks; if armor is strong enough to sensibly retard passage of a shell, the force of the explosion will be backwards, and although the head of the projectile may have penetrated, the damage done by splinters would be nothing in comparison to that which a projectile would make after having completely penetrated the plating. From this it would result that even against the most powerful guns, armor of 12 in. will render good service, as also slighter armor would against light guns. The theory of Captain Osborn points to other ideas upon the employment of armor; if the heaviest explosion of the projectile takes place from without and but the pieces enter, a lighter internal protection will suffice to ward off all danger. After all, we should consider the necessity of carefully experimenting to discover if two plates, distant 5 or 6 ft. apart, the outer one 7 in. thick and the inner of 5, would not give better results than a single plate of 12 in.; the first would break the projectile and the second would resist the pieces, no filling being interposed between the plates to allow full liberty to the dispersion of the explosive effect.

In one way or another, it is probable that it will become necessary to increase still more the thickness of armor plates, and that it will be necessary to advance boldly to a thickness of 10 or 20 in., but that will necessitate a diminution of the surface plated; something besides may be obtained by the abolition of the turrets, according to an idea expressed hereafter; if the length of the casemate can be reduced, it will perhaps be necessary, in addition, to abolish the armored belt outside the casemate, carefully protecting by means of the cellular system, the neighborhood of the water line; to reduce the dimensions of the upper works, to widen somewhat the casemate, to have the necessary means of locomotion, to obtain a satisfactory stability, it will be necessary to still more diminish the length and increase the width of ships. It being necessary to make these sacrifices, in order to have thicker armor, it is certain that the voice of those who propose its abolition will make itself heard more than ever; still it cannot yet be doubted that armor is a necessary evil.

The means of offence, except with regard to the active use of torpedoes, appear at present stationary; every ship is by nature a ram; guns may be produced up to a weight of 50 tons, but will probably be mounted in the same way; the use of powerful artillery is more important than ever; an arc of fire perfectly free, except as regards the intervention of the masts, has been obtained; also the details of the turrets appear completely satisfactory. However, it is possible that the necessity of reducing the surface to be plated, may lead to the substitution for turrets of Moncrieff's system, which allows the gun to be lowered beneath the shelter of the deck after every round. Offensive torpedoes, without doubt, offer an unlimited field to invention, but their employment does not seem to greatly modify the type of ships; to work them the enemy must be approached, and that naturally implies the necessity of stout plating to resist his guns, and good artillery to engage him. The small "torpedo ships," swift and unarmored, may be of use for a nocturnal surprise, which might be better carried out by a steam launch, or boat with oars; but it would be prudent for her in the ocean, in the light of day, to keep at a distance from the Devastation. A ship like the Devastation wants but a few simple additions to her prow, under water, to become the best type of "torpedo vessel;" Harvey's towing torpedoes and the use of booms for outrigger torpedoes—a powerful method of offence, too little appreciated on this side of the Atlantic—can be made use of quite as easily by the Devastation as by her diminutive and swift, but unarmored opponent. But these important improvements would not induce radical modifications in the construction of ships; torpedo appliances would, of course, be simply accessories; and even though the Moncrieff system be substituted for that of the turret, a ship like the Devastation could easily be altered; a low turning platform, the machinery for raising the gun, and a protection against water penetrating below, might be arranged without much difficulty; the gun would be a little less protected, and a weight of more than 100 tons would be saved; but turrets or no, it is probable that the central casemate will remain unaltered.

Also, the improvements in the motive power should be carefully studied; speed has become more than ever important from the serious dangers of the ram and the torpedo; and the engines of ships of war should answer as fully as possible to these three requisites:—1. Great power and reasonable economy at any speed. 2. The greatest security against the accidents that in time of action may render them temporarily unserviceable. 3. Facility of repair and power of isolating unserviceable parts.

To obtain these results it is essential to reduce the size of the engines, and especially of the boilers, and therefore to use only engines of a high pressure, which Mr. Reed recommends to be of at least 60 lbs.; he also recommends for iron-clads, the introduction of oval boilers, which, in spite of the inconveniences of cylindrical furnaces, admit of the most perfect utilization of the depth of hold; for un-armored ships he proposes to employ boilers made entirely of tubes, these being less liable than others to damage from shot; and with all engines, with a view to obtain the most perfect combustion possible, he recommends the use of ventilators to give a supply of air to the furnaces. Mr. Reed says that compound engines only produce economy of fuel by raising the pressure to double that of simple engines of twice the power; and he believes, that even with the latter, by increasing the pressure, almost equal results may be obtained, whilst there will be avoided the accidents so easily caused in action to compound engines on account of all the accessory gearing necessitated by the various dimensions of the cylinders and by their mutual dependence. With regard to weight, there will be no great difference between the engines of either type designed to work up to a pressure of 60 lbs., with the same capacity of expansion. Considering the position of the engine with respect to the hull, Mr. Reed is of opinion that, the dangers to be feared from rams and torpedoes being beneath the water line, the protection of engines placed low down is no longer such as to make up for the inconveniences springing from such a position,—as for instance, that of interfering with the water-tight compartments of the vital parts of the ship; when the protection of the armor allows it, vertical or oblique, engines may be used with advantage, and may thus be better distributed within these same compartments. The sub-division of the machinery will perhaps allow of its better protection, and may render less disastrous the consequences of an accident to any part of it. Mr. Reed would prefer to adopt exclusively double screws, and to divide the cylinder capacity between two pairs of simple expansive engines, also to give up to some extent economy of fuel; thus there would be two compartments of reasonable size instead of one very large one; one being at the extremities for the boilers and the other between the foremost and after boiler compartments; in this way may in general be used one pair of engines after the other has been rendered unserviceable.

These considerations may give rise to great changes in the internal arrangements of ships.

As to sea-going qualities, nothing certain can be asserted before the trial of the Devastation; then will be ascertained the result of having a prow of moderate height. To give accommodation to the ship's company, the armored deck has been lowered almost to the level of the water, throughout a distance of 50 ft. from the stern; the sides of the forecastle are 9 ft. high, and abaft they are between 11 and 12 ft. In the Fury, however, it has been judiciously determined to keep the whole of the armored deck at a height of 4 ft. above the water, otherwise it would be necessary to raise the level of the superstructures to that of the central part—which would prevent a depressed bow fire—or to give up those places as quarters for the crew for want of space. This is the opinion of Mr. Barnaby, who proposes a side of only 4 ft., with a flying bridge strengthened by girders, carried forward at the height of the present forecastle, for working the anchors.

Thus the low extremities will be well proved, and should the results be unfavorable, it will be sufficient to include the space under the flying deck, and try the 9 ft. sides afresh; but it is likely that this plan will not be carried out, and that the Fury will have in the bows a low forecastle above the armored deck, and abaft a side of 9 ft., according to the first plan. If the bows of these vessels should turn out to be too low, they may be raised 2 ft., or movable bulwarks may be added to the fore part, of sufficient strength to resist the sea. It seems, however, probable that the height given to the bows will be found sufficient, and that its volume will be found adequate to raise them above the breaking of the waves. It does not appear that any change has to be made in the sides amidships, already between 11 and 12 ft.; but the very low stern will not perhaps be equally approved of in practice, from its having a tendency to swamp the ship; the reason for making it as it is has passed away with the old superstition of a low freeboard. In existing ships, the stern may easily be carried to the same height as the bow, and thus will disappear the objection that the fore part would be exposed to a stern fire from a ship of greater power than the Devastation, or the Thunderer. In the Fury this inconvenience does not exist, because the breastwork occupies the whole width of the ship as an ordinary central battery with rounded ends. This change would probably be continued because it places all the berthing of the crew under shelter; berthing outside the armor, well lighted and well ventilated, will undoubtedly be preferable, and its destruction in action would not be important; but if the low bows, useful to allow of depressed fire, give good results, no other construction should be retained above water but the breastwork itself.

From these considerations it results, that for England, already protected by a most powerful fleet, it will not be prudent to begin at once construction of a new kind in the present uncertain condition of affairs; since her wisest policy is to halt for a short time, if she be always in time to equal anything good that may be launched in foreign dockyards; and the writer in the "Engineer" justly concludes, by recognizing the necessity of building other ships, but observing, that whilst it would be a grave error to construct at once ships similar to the Devastation, it would be a far more serious mistake to seek for designs before having tried her.

It is fitting, then, that Italy should profit by the experience of others, and proceed with the greatest caution to utilize as far as possible the few naval means at her disposal, because with us, as with other people, the preventive solution of the problem acquires a great importance. As has been well observed, it is not enough to build ships that may be worthy of comparison with those of other nations; but it is requisite for these ships to answer as completely as possible to the special interests of the country.

To the national navy has clearly been intrusted the defence of our extensive coast-line, and of the merchant vessels taking refuge in time of war in our ports. The fortresses on shore are certainly not adequate to the fulfilment of this object; to insure conviction, it is but necessary to glance at the map of Italy, and to consider for a moment what a vast number of fortresses would be required to protect the points at which a landing might take place, or even those places only which it would be specially desirable to preserve from the destructive effects of an enemy's fire.

Both fortifications and torpedoes will be of great utility, but they will be brought into practical use in but a few places, which the enemy will generally avoid; and what other protection can be given to the remaining portion of our coast, not sufficiently favored to be chosen as principal points for defence, but that of a squadron of ships? This possesses an immense importance, because it answers most completely to the duties imposed upon, and to the politico-military objects of, the navy. We have no colonies to protect; therefore in time of war the proper post of the fleet will be close to the shores of our country, which it has to defend; it need have no aggressive aims, but to be such as to cause every other navy to respect the integrity of the country, protecting the whole coast-line from the dangers of a bombardment and the perils of a hostile landing.

It is not, indeed, an easy question to decide which ships best answer to these requirements. At first the very natural idea presents itself to divide the iron-clad squadron into an offensive and defensive one—into ships, that is to say, destined to fight at a distance, and into others exclusively adapted to the defence of ports and roadsteads, and to inquire if such a division would, in its practical results, be really advantageous. What qualities should be expected in good ships of the squadron of defence? Great thickness of armor to secure the invulnerability of their own artillery, and the most powerful guns to inspire them with respect. As to motive power, although great speed would not be a necessary characteristic, still ramming attacks and offensive torpedoes, which will be much to be feared in future combats, demand that they should have good engines and that they should manœuvre with ease. But, with these characteristics, ships for defence would differ as little from those of offence as seems convenient, so that to divide the naval force into two distinct classes to adopt a single type for ships, which may, when occasion requires, act all together, is to insure success in cases of both attack and defence, or rather of passive and *active* defence.

To the special defence of certain points it will always be necessary to allot those iron-clads which the rapid progress of naval construction has left behind, and which, though inferior in fighting power to more recent ones, may prove of great assistance when supported by works on shore, or favored by the peculiar formation of the coast.

A doubt, then, arises if this continual progress will not render almost insufficient those ships which we propose to construct at present, but it seems probable that the practical limit will be reached by the projected designs, since there is a limit to the power of naval instruments of war, for it is not within the reach of human ability to pile up, in accordance with the conceptions of the imagination, great masses of iron on the ocean and manœuvre them with rapidity. It is therefore probable that, beyond the dimensions of the proposed plates, the studies of constructors will return rather to simplifying than increasing the means of defence; and then our present ships will not err by being too powerful and strong, a slight defect, for the special object of defensive operations.

Leaving out of sight the question whether or no a single type ought to be adopted for the construction of the new iron-clads, it remains to consider the proper qualifications. From the consideration that the principal aim of our fleet is not the destruction of that of an enemy, nor the possibility of fighting in distant waters, it would appear that we should not desire marine monsters, such as have composed the most recent squadrons; but that what is wanted is to have ships endowed with such powers of defence as to be able to withstand a hostile squadron in the event of military operations on our coasts, to hinder by its presence an enemy from attempting any important landing, and risking in our water that collection of transports which would be necesary to such an undertaking; and endowed with offensive powers to withstand effectually the enemy's guns, whenever he should attempt a cannonade. Moreover, although our squadron will not require immense supplies of fuel for long voyages, still its depots should be considerable, to supply the most powerful engines and to keep them in working order, for so long at least as the steamers of the higher class lines of packets which would be made use of for the enemy as transports in case of a landing.

The attainment of these requisites, so necessary to the security of the country, is beset by such complications that we must raise the ships, truly *floating fortresses*, to enormous, or, at least, to very great dimensions. It is better to utilize economy of fuel and of other stores so as to increase the power of the guns, as well as to decrease dimensions, in order to place these warlike engines well forward on the path of naval progress. In addition to the characteristics just mentioned, be it noted that with large ships we can have at sea a greater number of guns at less expense than we could have them with small vessels. The weight of a two-gun turret is naturally less than than that of two with one gun each, and the cost of a ship with two turrets is less than that of two ships with one turret of equal power. Considering the qualities of a ship as a ram, with the necessary strengthening to avoid the fatal consequences of a shock, and the facility of applying them to defence against torpedoes and the appliances to be taken advantage of as means of offence, better results will be obtained with ships of large size than with others.

There will not be wanting many to maintain, with the most excellent arguments, that the sums required for the construction of these iron-clads would be better employed in that of small swift vessels, without armor, carrying a single heavy gun, a kind of floating gun carriages, and it cannot be denied that such may turn out most useful in action, if they are ably and boldly handled and favored by fortune; but in accordance with the strict logic of the argument, they would have to succumb, in spite of their superiority in number, to the blows of an almost invulnerable enemy, and with a view to an important interest such as the defence of the coast, we cannot trust to accident nor voluntarily give up any chance of success. Beyond all, it is necessary to observe that these floating gun carriages, armed with a powerful gun and of great speed, can exist only in the imagination of their proposers, so insurmountable are the difficulties in the way of their construction with the characteristics required in them.

To be complete, our fleet must be composed, besides the above-mentioned class of line-of-battle-ships, of a class of secondary importance, intended for the protection of our commerce and for expeditions, rather maritime than war-like, in distant waters. Such a class would not have to be very large, since in time of war our merchant ships, not having free exit from the Mediterranean, would probably be shut up in our own or neutral ports. Such a class ought to be composed of cruisers, swift unarmored ships, carrying powerful guns, destined in time of peace for distant expeditions—being with that object provided with suitable spars and rig—and in time of war, to watch the movements of the enemy's squadron, especially cruising in the neighborhood of our coasts, their artillery would perhaps suffice to keep at a respectful distance an isolated vessel, and their speed would enable them to avoid unfavorable encounters and to chase merchant ships belonging to the enemy, at least when not prevented by principles of international law.

These few remarks have been offered with the intention of pointing to the development which the country imperiously demands for its navy; or rather it has been sought to attract to their argument the attention of intelligent men.

The defence of its coasts is one of those duties in which a nation, with respect to others, must not fail, and the equitable counter-balance of advantages which nature has bestowed upon the country, by circling it about with the sea, opens to it, in the rich paths of commerce, a life that inland people may envy. Italy will not be slow in reaching that commercial development which awaits her; our flag begins to show itself less rarely in the waters of the extreme East, many ships are constructed upon our shores, and this commercial progress will increase even still more when once it shall feel itself better protected.

It is necessary to recollect that to overlook the defence of our country's shores may one day perhaps be the cause of irreparable losses, and that prudence and duty counsel us to consider minutely every requisite for its persevering fulfilment. The question of our fighting fleet has been considered with the greatest attention, so that we may not have hereafter to bewail the consequences of over-confidence, of a too rigid economy, or even of the too great levity of former years.

Ships of war must be our fortresses for hundreds of miles from the margin of the sea, and in time of need; and repentant regrets will not suffice to protect our immense coast line, nor the numerous building slips, the merchant ships, the vast and wealthy cities so exposed to the attacks of a hostile fleet.

TESTS OF STEEL.*

By A. L. HOLLEY.

From the "Iron Age."

The intention of this paper is not to discuss this important subject in all its bearings, but merely to point out why mechanical tests of steel, as ordinarily made, are not, alone, of any special value to engineers —certainly not to general mechanical engineers.

The agents of the Barrow Hematite Steel Company, one of the largest and most successful Bessemer establishments in England, have recently distributed a report made by Sir William Fairbairn, on the transverse, tensile, and compressive resistances of certain bars of this steel. The number of tests is very large; they seem to be careful and minute; and the modulus of elasticity, the work up to the limit of elasticity, and the limit of working strength, are fully tabulated according to the latest formulæ.

This is very well—indeed, it is indispensable, as far as it goes; but it goes no further than to inform the ordinary engineer that there is an unknown substance which possesses these physical properties. As to what the substance is, the report gives him no working knowledge, for not a single analysis is given of any of the bars tested. The most that is said of some of them is that they are either "hard" or "soft," which is sufficiently evident from the experiments. "A bar of steel" is, in the present state of the art, a vastly less definite expression than "a piece of chalk." To the engineer who wants steel for a specific purpose, it gives only the faintest clue, to say that steel is hard or soft. There are a dozen grades of both hard and soft steel, adapted to different purposes. Rail steel is soft, and boiler plate steel is soft, as compared with many structural steels, and with the whole range of spring and tool steels; but the one perfectly adapted to rails would be useless for boilers.

In order that engineers may know what to specify, and that manufacturers may know not only what to make, but how to compound and temper it, the leading ingredients of each grade of steel must be known. Pure iron would be unfit for nearly all structural purposes. Upon the substances associated with it depend its hardness, malleability, stiffness, toughness, elasticity, tempering qualities, and adaptations to various structural uses. These ingredients are, indeed, impurities, but the term "impurity" unfortunately implies a defect, whereas the thing may really impart the essential quality. All the usual ingredients give what is called "body" to steel. Carbon, within specific limits, as is well known, gives hardness, elasticity, resistance to statical strains, and tempering qualities. Under

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*Read before the American Institute of Mining Engineers, t Easton, Pa., Oct. 22. 1873.

certain conditions of composition it even gives resistance to sudden strains. Manganese (and this fact, by the way, is not so generally known) gives, in different proportions, hardness, toughness, malleability and elasticity. Chromium imparts similar qualities, but to what precise extent we do not know, in default of a proper comparison of chemical and mechanical tests. Silicon, although considered a bane by steel makers generally, and, singularly enough, advertised as the great panacea for the weaknesses of steel by certain modern inventors, has probably, in proper proportions, a healthful influence on the physical properties of steel. Even phosphorus, the arch enemy of the Bessemer and open hearth manufacture, may, in some degree, be a valuable ingredient.

Whether or not certain foreign substances, which, separately added, produce similar results, would produce a better result if combined in certain proportions—for instance, whether carbon alone in any degree, or silicon alone in any degree, would make as good a steel for certain uses as carbon and silicon combined, it is, in default of proper experiments, impossible to state. The probability is, that there is a proportion of carbon and manganese which would give the highest possible value to all structural steels. We formerly added spiegeleisen to decarburized Bessemer metal solely to impart manganese to the oxygen of the oxide of iron formed in the Bessemer process.

We now add a larger proportion of spiegeleisen, not only to remove the oxygen, but also to mix manganese with ths steel. And we think we find that if the proportions of silicon and phosphorus are sufficiently low, and carbon does not exceed a third of one per cent., manganese to the amount of three-quarters of one per cent. gives the resulting product a high degree of toughness and hardness combined—a degree of suitableness for rails which no proportion of either carbon or manganese, not associated, can impart.

When we consider that two or three tenths of one per cent., and, in some cases, a fraction of a tenth of one per cent. of foreign metals, will change the character of steel in a high degree, and when we farther consider that the physical results of these combinations have never been tested or analyzed in any thorough and comprehensive manner, we may well reiterate the common expression, that the iron and steel manufacture is in its infancy.

But it is not necessarily in its infancy. We simply do not develop it. The general complaint of engineers and machinists is, that they occasionally get, but can never get regularly, the precise quality of steel they require; and yet it is probable that thousands of tons of steel have been made which are suitable for each of these purposes, but have been used for others, and that the precise grade required in every case could be reproduced by the 10,000 tons. The trouble is that neither the user nor the makers know what the material is. They have put no mark on it by which they can recognize it; they have kept no recipe. All they can do is to use ingredients of the same name, and approximately the same quality, and to guess at the physical properties of the product, aided by such crude tests as can be made during manufacture. Mr. Wm. H. Barlow, in a late address on modern steel before the British Association, says that one reason why steel is not more used for structural purposes is, that the metal is of various qualities, "and we do not possess the means, without elaborate testing, of knowing whether the article presented to us is of the required quality." But neither Mr. Barlow, nor any of his associates in Government experiments, proposes the true solution of the difficulty. It is no more necessary to test one or two of each lot of bars to destruction, in order to find out the quality of the rest, than it is to burn up a Chinese village to get roast pig.

If the user would *analyze* not one, but twenty samples of the steel that meets a particular want, and then base his order on an analysis that should come within the highest and lowest limits of the samples, he would get substantially the same metal every time. The problem is a more difficult one for the steel maker, since he must analyze the many materials that go into his product; but if he imposes the same restrictions on the makers of these materials —in short, if from the ore and limestone and coal, up to the finished bar, each user buys by analysis, and pays in proportion to uniformity, the production of steel of the most multiform grades and qualities, each homogeneous and uniform to any extent of production, becomes a possible, if not a comparatively easy, matter.

What are Sir William Fairbairn, and Mr. Barlow, and Mr. Kirkaldy, and the other great experimenters in the physical properties of steel—in its adaptation to certain specific uses—what are they doing to relieve the engineering from these uncertainties? They are simply discovering the vast number of qualities which steel may be made to possess, without giving more than a clue to the method by which these qualities may be predetermined and reproduced. They are going to a vast expense of time and material to inform us, not that a certain combination of metals, but that a *bar of steel*, has such resistance and elasticity. This sort of experimenting has much the same value as the steam engine tests of a late chief engineer in the navy, of whom it is said that in a coal consumption test he would calculate the ashes to ten places of decimals, and guess at the coal put into the furnaces.

Moreover, Sir William Fairbairn may be doing injustice to other steel makers, to Brown, Cammell, and Bessemer—bars of whose steel he has also similarly tested, and found not quite so good for certain purposes as the Barrow bars are. But he neglects to make it clear that the disparaged bars may be better than these particular Barrow bars for other purposes. He makes the mistake, which we should suppose Sir William, of all men, would, not make, of being absurdly general and random in one element of his conclusions, while he is fractionally accurate in others—of cramming the whole matter of chemical ingredients into the terms "hard" and "soft."

The first and easiest step in the desired direction is to find out what X is. It is not necessarily a bar of steel made by Turton & Sons, which one tool maker will swear by and another swear at; nor is it necessarily a boiler plate steel which Park Bros. made once, and Firth got at twice, and Singer, Nimick & Co. hit two or three times. It is a steel which Turton, and Firth, and Park, and Singer can, either of them make by the 10,000 tons, if you will only tell them what it is made of, as well as what its physical qualities are. In the various uses to which engineers have applied steel, there are a vast number of specimens which have long fulfilled all the requirements. When more steel of the same sort is wanted, the usual method is either to apply to the same maker, who kept no complete record, and does not know what is wanted; or to get bids based on a stereotyped and very inadequate physical test, for instance, that the bar must stand such and such a blow from a drop. The lot of steel is made, and is, as well it may be, very heterogeneous in physical character, although it may be in accordance with the one test. The result is, that, under wear, some of it fails, or, under load, an excessive margin of safety must be allowed. The obviously rational way to reproduce a lot of steel which is proved suitable for any purpose, is to analyze many samples of it—at least for carbon, manganese, silicon, phosphorus, and any element which exceeds $\frac{1}{10}$ of 1 per cent., and thus to give the steel maker a recipe for making it.

It may be suggested that this chemical synthesis of steel will be ruinously costly. For certain exact purposes, such as the members of a long span bridge; or, for certain fine purposes, such as gun barrels, the cost of analysis, or any loss in applying to other uses the lots of steel that were not up to the mark, would be very small compared with the extraordinary margin of strength that must be given to an uncertain metal, and compared with the cost of occasional failures under final test. And this cost, whatever it is, the user, that is to say, the public, should and must bear.

But steel makers will find that working by analysis is not so very formidable, after all. The color test of carbon is already applied to all charges of all Bessemer and open hearth makers, and it is one of the most important. There is another view of the case: After a certain experience in comparing mechanical tests, which are comparatively easily made, with the more costly determinations of manganese, phosphorus, etc., the expert will not need to analyze every charge. He will learn to read manganese, approximately, in an elastic limit test, just as the expert blacksmith can now read carbon quite accurately by the water-hardening test. Herein will lie one of the values of the combined mechanical and chemical tests—that they will supplement and prove each other.

When the proper amounts of carbon, manganese, silicon, etc., for certain uses are known, it will not be impossible to approximate to them, in the Bessemer process, to a very helpful degree, and in the open hearth and crucible process, to a reasonably accurate degree. Of course, the character of the ingredients must be much more definitely known than at present, and numerous batches of nominally the same ingredients, such as pig iron, blooms, or puddle balls, must be mixed, so as to largely dilute any high degree of impurity which any one batch may contain.

The thing first in order is, of course, to ascertain the mechanical properties of all grades of steel—not merely the individual resistances to destructive strains, which are but the stones that compose the mosaic, but the resistance within the elastic limit, which is the finished picture. To this end experiments like those of Sir William Fairbairn are indispensable, but to these must be added analysis of every grade of steel that can be produced, or the character of the metal is but half known.

In the present state of constructive and metallurgical art, it thus seems not only vitally important, but highly feasible, to increase in a large degree the uniformity of all grades of steel, and to make grades adapted to all special uses, instead of following the hit-or-miss and large-margin system, or want of system, that now obtains. Of course the change must come slowly, and its early stages will be attended with difficulty and expense; but there can be no question as to its ultimate success and its immense advantage in constructive and manufacturing engineering and art.

What probable expense of experimenting is to be considered when it will increase, possibly double, the resistance of metals to specific stresses, and decrease the present enormous margin of safety? It seems unaccountable that Government commissioners have so long neglected the chemical half of the problem—have so long neglected to complete the circuit, so that the metal will tell us its own story.

DERAILMENT.

From "The Engineer."

We have given in another place a short summary of twelve months' accidents in this country and the United States. We shall not reproduce any of the figures here, but we commend the statistics to the attention of our readers. It will be seen that the railway system of the North American continent, notwithstanding its imperfections, is worked somewhat more safely than our own. We shall not attempt to consider to what cause this is due; our purpose, for the moment, is to consider whether railway "accidents" are or are not inseparable from locomotion on iron roads; and to do this it will be necessary to define the sense in which we for the moment use the word "accident." We do not intend it to apply to cases where railway servants are crushed between buffers, or are run over when crossing lines; nor to the falling between trains and platforms of persons who insist on entering or leaving carriages in motion; but to refer the term exclusively to those cases in which trains get off the rails. Now, even with these limitations, it will be seen that the subject is a very large one indeed, and will bear examination from many points of view. With a little care, however, certain aspects of the question may be completely eliminated, and the history and progress of railway catastrophes of the more obtrusive kind may be in a great measure simplified, and brought within reasonable limits of reflection.

It is evident, to begin with, that a very large proportion of accidents are due to derailment, and although it is not quite so evident, there is still excellent reason to believe that very many more trains get off the rails in summer than winter. On the other hand, many more axles and rails are broken in winter than in summer, and so the balance is preserved. Indeed, each season of the year appears to have its own special class or type of accidents, and we venture to say that as nothing occurs without a cause, so a careful digest of the statistics and particulars of each season's accidents will be found eminently instructive, and may, indeed, be utilized in designing means of avoiding the occurrence of catastrophes almost or altogether. For example, why should more trains get off the line in summer than in winter? Why should more axles and ties break in winter than in summer? The answer to the last question is very simple. Jack Frost smashes our tires, and axles, and rails, and his mode of operation is well understood. In the first place, whatever theorists may say, it is almost indisputable that iron and steel are more brittle when the temperature is below freezing point than when the thermometer stands pretty high; and, in the second place, a frost-bound road has little or no resilience or elasticity, and all the shocks which rolling stock encounters as a result of imperfection in permanent way are magnified and intensified in amount. These facts are so well known that on many foreign railways where the winters are intensely cold, the speeds of all trains are reduced to lessen the strains to which the lines and the rolling stock are exposed. So far it is all plain sailing; when we come to consider why it is that more trains get off the line in summer than in winter, it is not a case of plain sailing at all. On the contrary, we are met at every turn by difficulties sufficiently great to almost dispose us to doubt the evidence of our senses, and to assert that just as many trains get off in winter as in summer. If we accept broken rails, tires, or axles, as causes of derailment, it is no doubt true that in winter more trains are off the road than in any other time of the year; but we wish to expressly eliminate such causes of derailment, and to refer exclusively to those accidents in which a train apparently gets off without any reason; and handling the subject in this way, we think we can show that a high summer average of derailment accidents is no more than is to be expected under the existing conditions of railroad construction and working.

If a railway were perfectly smooth, even, and straight, and if the line of draught of carriages passed directly through their centres of gravity, there would be no derailments. Indeed, with perfectly cylindrical tires, and a perfect equality of resistance at every point, flanged wheels would not be required, except to provide for the action of the wind, because there would be no reason why a train, once set fairly on the rails, should be induced to leave them. In practice, however, there is no such thing as a perfectly even and smooth line of rails; the centre of tractive effort does not coincide with the centre of gravity; there are plenty of curves to be run over, and, in short, the road and the rolling stock are both far removed from perfection. Now, all railway men will agree with us when we state that whether a train keeps on the rails or resorts to the ballast instead, at any given speed, is purely a question of the good and bad qualities of the road and the rolling stock. For example, there are tracks to be found, even in England, over which it is not safe to travel at more than 10 miles an hour, and there are also tracks over which we should be quite content to risk our lives at 100 miles an hour. Between these limits there are all kinds of roads, which may be classed as 20 miles, 30 miles, 40 miles an hour tracks, and so on. In like manner there are 20 miles, 30 miles, 40 miles, even 70 miles an hour engines and carriages. If a road were all of the 20 miles, or all of the 40 miles type—of any fixed type, indeed, throughout—the work of running trains would be much simplified, and the risk of derailment would be much diminished. As a fact, however, in the middle of a length of, perhaps, 100 miles of 45 miles an hour permanent way, we come upon a mile, or two of 20 miles an hour road. Over this trains run for years, and safely, apparently at least. No one knows how bad the bad bit is but the driver—there is nothing like standing on a footplate to know where a rough mile comes in. At last it so happens that a 20 mile carriage comes at 45 miles an hour on to the 20 mile bit of road. Then comes derailment, and a coroner's inquest, and a Board of Trade inquiry, and the road is examined, and said to be very good, and the engine-driver is examined, and he says he can't explain it, and the stoker knows nothing about it—stokers never do, *vide* coroners' inquests—and the inspector of permanent way says it is a splendid bit of road; and the foreman of the carriage department is certain that a more perfect vehicle than that which left the rails never was built; and so, according to the evidence, an accident ought not to have happened, and a very little more evidence would convince the jury that no accident ever took place, and would persuade those who travelled by that particular train that they were really enjoying a species of Barmecides feast of contusions, and cut heads, and broken legs, and slaughtered relatives; and, finally, the public are assured that the accident was wholly inexplicable, and another railway company kindly steps in and diverts attention by supplying another accident, which ought not to have happened, but has happened with more sensational characteristics than the first, which is straightway forgotten, attention being concentrated on the second, which only gives way to a third, and so on. The derailment in such cases as these is obviously due to running over a bad bit of road at too high a speed—a thing which may be done with comparative safety if the vehicles are in first rate order, properly loaded and with wheels in the best possible condition. The fortuitous encounter of a badly running carriage, badly loaded, with a bad bit of road, causes a smash, and the obvious lesson to be learned is that for high speeds both roads and carriages should be in perfect order. Now let us see how all this applies to the fact that there are more derailments in summer than in winter.

In the first place, then, more repairing of the road is done in summer than in winter. There is more renewal and packing of sleepers, and so on. Drivers of engines know very well that there are extremely dangerous places on a road under repair, just where the old and untouched part joins the new. We have often felt an engine lurch right and left, and reel like a drunken navvy, on getting on to a newly laid bit of road which had not had time to settle. In packing all old roads, again, it is the practice to pack them a little too high, to allow for settlement. The first few high-speed trains over a road thus treated "catch it," to use a very expressive if not very elegant phrase. A disturbed road, even when disturbed with the best intentions, is always a dangerous road for high speeds; and a very small gang of platelayers will suffice to reduce a mile or so of road from fifty-mile condition to twenty miles an hour condition in a couple of days. Of course the road settles after a time, and is better than it was before; but while the settlement is going on it is not a safe road for high speeds. If more roads be disturbed in summer than in winter, this is one reason why derailment is more likely to occur in June than in December. In the second place, more trains and longer trains are run in summer than in winter, and as very few railway companies have more stock than they want, all kinds of vehicles are pressed into service, and thus old worn out carriages may be found running in company with first-class stock at first-class speeds. As these inferior carriages generally pay the penalty of utter destruction for their offence when they get off the line, it is not easy to convict them. If the catastrophe takes place at night, the fragments are used to light up the scene, and to destroy every trace of evidence which could convict the erring vehicle. Furthermore, though carriages are run from seaside towns on branch lines, and miserable vehicles which have spent years, perhaps, in pottering backwards and forwards two or three times a day over a couple of miles of road at about fifteen miles an hour, behind a wheezy old cripple of a locomotive, find themselves tacked on to to the tail of a main line train, drawn by a magnificent express engine, and they are thereupon whisked across country sixty or eighty miles without stopping. Is it matter for wonder that the small remains of vitality they possess should be unequal to the strain thus put upon them? So long as the road is good they get on somehow, especially if they are put near the middle of a train and steadied before and behind. At last they come to a bad spot in the road and they incontinently depart from the track and are no more heard of except as so much match-wood. And this running of branch line carriages on the main line in summer is, we admit, another and a most potent reason why more derailments take place in summer than in winter. One other cause and we have done. In summer much longer trains are run than in winter—it was our fate last week to travel in a carriage not new in the middle of a train of 27 vehicles, drawn by two engines, and on one occasion we ran about ten miles at a speed varying between 52 and 59 miles an hour. In theory there is no reason why a long train should be more liable to derailment than a short one; but in practice there is this very serious objection to long trains, that however tightly the draw bars may be screwed up, the buffers will not be in contact when the train is running, because the tension spring is so much compressed by the excessive strain on it. This is the reason why the leading carriages of a long train lurch so much. It is because longer trains are run in summer than in winter that more cases of derailment occur during the tourist and sea-side season than any other time of the year.

What are the lessons to be drawn from these facts? Firstly, that on high speed lines there should be no weak places in the road, and secondly, none but the most perfect rolling stock in the train. A good road will compensate for bad rolling stock, and *vice versa*, and many engineers reckon on the good qualities of their stock to compensate for a bad road; but their sin is sure to find them out. Some day a carriage gets into a fast train which should not get in—bad road and bad carriage meet, only to part company for ever. No amount of vigilance will provide for such a case. In one word, these first-class speeds require first-class roads and first-class stock. With them, sixty or seventy miles an hour are safe; without them, only a high speed is required to insure the occurrence of an accident, especially in summer.

REPORTS OF ENGINEERS' SOCIETIES.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS.—At the annual meeting in November the following list of officers was elected:

Col. Julius W. Adams, President; Col. W. Milnor Roberts and Gen. Theodore G. Ellis, Vice-Presidents; Mr. Gabriel Leverich, Secretary; Mr. James O. Morse, Treasurer; Messrs. John Bogart, Charles Macdonald, and Francis Collingwood, Prof. De Volson Wood, and Mr. Octave Chanute, Directors.

Amendments to the Constitution of the Society, proposed at the regular meeting held October 15th last, were taken up in order, article by article, and the following only were adopted:

ART. 4. Civil, Military, Geological, Mining and Mechanical Engineers, Architects, and other persons who, by profession, are interested in the advancement of science, shall be eligible for admission in their appropriate class.

ART. 16. The active members of this Society shall be divided into three classes, to be styled respectively, Members, Associates, and Juniors; and each person, when duly elected and qualified, shall receive a certificate of membership, indicative of the peculiar class which he represents. Associates and Juniors shall possess all the rights and privileges of Members, excepting the right of voting.

ART. 17. To be eligible as an Associate, the candidate must be one whose connection with science or the arts qualifies him to concur with civil engineers in the advancement of professional knowledge. To be eligible as a Junior, the candidate must have been in the actual practice of his profession for at least two years.

ART. 19. All candidates for admission to the Society must file statements by themselves, setting forth the grounds of their claim to be elected; be proposed by at least two Members of the Society, to whom they must be personally known, and a notification of the same sent to each member whose place of address is on record. Each proposition, with the names of the proposers, must be posted in some conspicuous place in the rooms of the Society, for at least thirty days before being submitted to vote. All such papers and applications shall be laid before the Board of Direction, and be reported upon, previous to action by the Society.

ART. 20. In elections for membership of either class, Members shall vote by letter, or by ballot in the usual way, and the result shall be announced at the next regular meeting held after thirty days have elapsed from the time of mailing the notification Three or more ballots cast in the negative shall exclude. Members notified but not responding, shall be classed as having voted in the affirmative.

ART. 22. Persons thus elected and duly qualified, who reside in the City of New York, or within fifty miles thereof, shall be deemed Resident; and those who reside beyond those limits shall be deemed Non-resident.

ART. 23. The amount of entrance-fee to be paid, as well as the annual dues or assessments for the support of the Society, shall be determined from time to time, at some regular meeting of the Society, provided that notice of intended action thereon shall have been given at a previous regular meeting. No alteration in the amount of said fees or assessments shall apply to the fiscal year during which it is made, but shall take effect on and after the first Wednesday in November next succeeding the day of the date of said alteration.

ART. 29. Resident Members, Associates or Juniors, who may remove beyond the limits prescribed in Article 22, for the term of one year or more, shall be subject to the payment of such fees and assessments only as are prescribed for Non-residents, provided that the person thus removing shall give the Secretary of this Society written notice of such removal. This privilege, however, shall not apply to any fractional part of the fiscal year.

ART. 30. Every person admitted to the Society shall be considered as belonging thereto, and liable to the payment of all assessments, until he shall have signified to the Secretary his desire to withdraw; when, if his dues have been fully paid up, his name shall be erased from the list of members.

ART. 31. Any person admitted to the Society, who shall refuse to pay any assessment or other dues to the Society, or who shall neglect the same for the term of six months, after due notice is issued in the Form C, in the Appendix, shall cease to be a member.

ART. 35. Proposed amendments to this Constitution shall be first submitted to the Society, and seconded, and then sent by letter to the several Members of the Society, at least twenty-eight days previous to the Annual Meeting. Such amendments shall be in order for discussion at such Annual Meeting, and shall be voted upon by letter-ballot, within sixty days after the date of said meeting. The votes shall be counted by the President and Secretary, and if two-thirds of the votes are in favor of said amendment, it shall be declared adopted, and the result announced at the next regular meeting of the Society thereafter.

ENGINEERS' CLUB OF THE NORTHWEST.—Mr. E. S. Chesborough recently read a paper before this Society on Conveyance of Water and Repair of Pipes under Navigable Streams.

The existence of navigable streams in the heart of a city had, until late years, been considered a great obstacle to the conveyance of water by pipe across them. Wherever fixed bridges were used, the pipe could be carried across without difficulty, but where there were draws it would be necessary to have pipes along the bottom or in tunnels. The Babylonians are said to have had a tunnel beneath the Euphrates, but very little is known about it. The earliest instance of carrying water across streams was that of Watt, of Glasgow. The next instance, as in the case of Watt, by flexible pipes, was that employed by W. S. Whitwell, between Boston and Chelsea. Ward's joint, a comparatively recent invention, by its economy, simplicity and inflexibility, has come into general use for flexible pipes, and has several patented improvements. Another plan adopted at the crossing of the Charles and Mystic rivers by the Boston Water Works, was to lay the pipes by the side of existing pile bridges, above high water mark across the shallow portions, and to place inverted syphons under the channels at the draws. These, put together on shore, were made by boxing around the pipe with heavy timber, having a sufficient space between the pipe and wood to be filled with cement to protect the iron from the salt water. All pipes under water should be provided with some means of removing deposits. When not large enough to admit a man, they should be provided with "blow-offs" near the surface of the water. The great importance of being able to reach at all times a break or defect has led to the adoption of tunnels under navigable waters. The first on record in this country appears to have been that of Eddy, of Boston, passing under the Charles river, though there are now many in use in this country and Europe. Mr. C. described some of the difficulties of repairing pipes beneath the surface, illustrating the subject by reference to the leaks repaired in the Chicago avenue and Rush street pipes beneath the river in the city. In these cases the pipes first used were simply of boiler iron, joined and sunk into trenches, formed by dredging. They were often injured by anchors, driving piles, etc., and therefore tunnels have been made at Rush street, Adams street, Chicago avenue, Archer avenue, and two beneath Division street. There is also a 36-inch pipe through the La Salle street tunnel. The other pipes are 24-in., laid in tunnels 6 ft. in diameter. This gives room for workmen to make repairs.

IRON AND STEEL NOTES.

With reference to the tensile strength of Lake Superior iron, the Detroit "Free Press" makes a record of the following experiments with iron made from Lake Superior ores, by the Wyandotte Company. A bar of railroad iron was put under the hammer, and bent, twisted, and tortured until no resemblance of the original bar remained. An effort was then made to hammer the head of the rail from the flange, but it proved unsuccessful. It must be understood the experiments were made when the iron was cold. The experiments with the chains were equally satisfactory and showed a great power of resistance. A Bessemer steel chain, 1¼ in. in thickness, withstood a test of 121,850 lbs. to the square inch. The following comparisons will show the relative tensility of Lake Superior and English iron, the trials having been made by the use of the testing machine made by Riehle Brothers, of Philadelphia, which is that used for all tests in which the American Government is concerned. A one-fourth inch chain of American (Lake Superior) iron withstood a strain of 101,750 lbs., while a chain of English iron of the same size broke at a test of 76,500 lbs. A five-eighth inch chain, American, 24,875 lbs.; English, 16,000 lbs. A three-fourth inch chain, American, 38,000 lbs.; English, 26,000. A one-half inch chain, American, 15,825 lbs.; English, 8,500; and a seven-sixteenth inch chain, American, 10,250 lbs.; English, 5,750.

Preservation of Sheet-Iron.—The results of some experiments in regard to the preservation of sheet-iron used in railroad bridges have been published by the Directorate of the Government Railroads of the Netherlands. From thirty-two sheets half was cleaned by immersion for 24 hours in diluted hydrochloric acid; they were then neutralized with milk of lime, washed with hot water, and while warm dried and washed with oil. The other half was only cleaned mechanically by scratching and brushing. Four of each kind were then equally painted with red lead, with two kinds of red paint of oxide of iron, and with coal-tar. The plates were then exposed to the weather, and examined after three years. The result was:—1. That the red lead had kept perfectly on both kinds of plates, so that it was impossible to say if the chemical cleaning was of any use. 2. That one kind of iron oxide red paint had better results on the chemically treated plate than on the other: in fact, a result equal to that of the plate painted with red lead, while the other kind of iron oxide red gave not very good results on the plates, when only scratched and brushed. 3. That the coal-tar was considerably worse than the paint, and had even entirely disappeared from those iron sheets which had not been treated chemically, but only cleaned by brushing.

Steel Boiler Plates.—Mr. L. R. Haswell, Engineer of the Austrian State Railway Company, in an address delivered before the Society of Austrian Engineers, remarked that the accidents which had occurred on railways using locomotive boilers of steel had thus far been only ascribed to the material; yet this was due, on the one hand, to the preparatory working of the plates, and on the other, to the small thickness, as well as to the insufficient mode of assorting them before they were used. The State Railway thus far has used about 50,000 cwt. steel plates, among which only 200 cwt. were thrown aside during the manufacture of the boilers. Mr. Haswell only knows of five instances where such boilers got cracks, four of which occurred in the fire-box-plate and one in the cylindrical part. He ascribes their faulty condition to the fact that they were rolled when too warm. This shows that even by purchasing steel plates from the most renowned establishments and of the best quality, one cannot depend on their superiority for the purpose in question, without assorting them with the utmost care, because it can readily occur that in heating the plates one or more get spoiled. Hence, in the establishments of the State Railway all plates are subjected to tests for their tensile strength before they are used. That these tests are perfectly reliable is shown by the fact that of 350 boilers consisting of steel plate, only a single one was found torn thus far, and this in the cylindrical part. The box plates not having been tested, it is readily explained that four boilers were injured in those parts. But, although these plates had undoubtedly been impaired in their strength by overheating, they would probably not have been torn if the construction of the machines, namely, the boiler supports, did not involve an immense strength.

In order to obtain steel boilers answering all requirements, only correspondingly thick plates and plates of the best material, without any addition (for otherwise the steel is not homogeneous), ought to be used; they ought to be scrupulously assorted according to the texture and tensile strength. After boring, or punching, they should be carefully annealed, the riveting must be performed with pedantic care, and the bending only with wooden hammers. That steel plates manufactured in Austria are of excellent quality is proven by the manner how boilers are there constructed; the box front plate, down cover, and the sides of the tubes are only furnished with an edge, or border, while in England they are compelled to use angle iron for these connections.

Steel plates are preferable to iron plates, owing to the fact that they possess the same degree of elasticity in all directions (from 12 to 15 per cent.); in iron plates it is in the direction of the fibres, and according to Kirkaldy, about 15 per cent., but in a cross direction only 5 per cent. If one proceeds in the manner indicated, says Haswell, steel plates may be used with perfect safety. The boiler manufacturer has the advantage that he finds less plates to throw aside, and the railways, on the other hand, will have more carefully constructed, stronger, and, in the end, cheaper boilers.

PATENT FURNACE TOP.—We hear good accounts of the working of Harris' Patent Furnace Top. Aside from the increased convenience in working the furnace, a great gain in economy is claimed by many who have used the "Top" during the past two years.

THE IRON TRADE.—From the annual report of the Iron and Steel Association, we make the following brief abstracts :

The year 1872 opened with an increased demand for iron in nearly all civilized countries. Prices advanced rapidly in all markets. The supply was unequal to the demand, although production was everywhere stimulated. In the United States forty new blast furnaces were erected, and the erection of others was undertaken—the foreign demand for British iron and the increased cost of producing that iron leading to the reasonable presumption that our people would now be able to possess their own iron market.

PRESENT CONDITION OF THE IRON TRADE.

The high prices for iron of all descriptions which had prevailed in the United States in 1872, gradually declined during the latter part of that year, and this decline, with some effort at a rally in January, continued during 1873.

The production of pig iron in the United States in the year 1872 was 2,830,070 net tons, or 2,526,848 gross tons. This quantity was produced in twenty-one States. The ascertained production during the first 6 months of 1873 was 1,393,075 net tons, and the estimated production for the whole of the year 1873 is 2,695,434 net tons, or 2,406,637 gross tons. The number of States which made pig iron this year was twenty-two—Maine having re-entered the list after a long rest. The excess of production in 1872 over the estimated production of 1873 is 134,636 net tons. If the financial crisis had not occurred, the production of 1873 would have exceeded 3,000,000 net tons. The estimated annual capacity of all the furnaces in the United States is 4,371,277 net tons.

The total number of furnaces in the United States, exclusive of abandoned and projected furnaces, is 636. The total number of new furnaces finished and put in blast in 1872 was forty-one ; finished and put in blast in 1873, forty-two ; total number of new furnaces put in blast in the last two years, eighty-three. Many of these are among the largest in the country. By the erection of these eighty-three furnaces, the furnace capacity of the country has been increased fully one-fourth.

Pennsylvania still maintains her position at the head of the States which make pig iron. In 1872 and again in 1873 her furnaces produced very nearly one-half of the total yield of the whole country. The three Western States of Michigan, Wisconsin and Missouri, with sixty-four furnaces, have this year made one-tenth of the total yield.

There is one furnace in Texas, which is making pig iron this year. It is situated near Jefferson, in Marion county. A letter to this office from Mr. H. C. Hynson, of Jefferson, states that extensive and valuable iron mines exist near that place, which can be bought at five dollars an acre. Coal can be obtained at fair prices, and excellent railroad facilities exist. The Texas and Pacific Railroad will undoubtedly open up rich deposits of both iron ore and coal in Texas. Over two hundred miles of this road are now finished and in operation.

It is somewhat remarkable that there is no furnace in Delaware. Forty years ago there were many charcoal furnaces and other iron works in Sussex county, in this State, which produced iron of the best quality. There is yet an abundance of excellent ore in the county, and both anthracite and bituminous coal can easily be obtained for smelting it.

Summary of Iron and Steel Production.

Below is a summary in net tons, of the ascertained and estimated production of iron and steel in the United States in 1872 and 1873:

	1872.	1873.
Iron and steel rails..............	941,992	850,000
Other rolled and hammered iron...	1,000,000	980.000
Forges and bloomaries...........	58,000	50.000
Cast steel........................	32,000	28,000
Bessemer steel	110,500	140,000
Siemens-Martin steel.............	3,000	3,500
Pig iron..........................	2,830,070	2,695,434

Railroad Construction.

We estimate the mileage of new track for the year 1873 at only 3,000 miles, a decrease since last year of more than 50 per cent. The year 1871 witnessed the culmination of railroad construction in this country. The number of miles built in that year was 7,779. The reaction commenced in 1872, when 6,427 miles were built. The total railroad construction of 1874 is estimated at 3,000 miles, the same mileage as the estimate for 1873.

RAILWAY NOTES.

The International Bridge Finished.—The Buffalo "Commercial" announces that the great International Bridge, crossing the Niagara River at Black Rock, and connecting the United States of America with the Dominion of Canada, is at last completed. The first caisson was launched on the 13th of July, 1870, and work progressed steadily up to the time of completion. The bridge was practically finished this week, by the winding up of work on the last span. The entire cost of the International Bridge, in round numbers, is not less than $1,500,00). Of its practical benefits we leave the reader to judge, merely stating in conclusion that it supplies a want long been felt by the different railroads which have for so many years been obliged to cross the Niagara River on the steamer International. The bridge has been leased to the various railroads which will cross it, for twenty years. The roads are the Grand Trunk, the Great Western, the Canada Southern, the New York Central, the Erie, and the New York, West Shore and Chicago. Most of these railroads have already constructed their approaches to the bridge, and will commence sending trains across at as early a day as possible. A railway track is laid over the bridge, and also a sidewalk for foot-passengers. The original plan contemplated a carriage-way as well, but this was abandoned for the reason that, as the bridge was three-quarters of a mile long, and so many trains were to cross it, there would very seldom be a chance for carriages to cross without interfering with the trains. Hence it was thought best to give up the idea of a carriage-way altogether.

ENGINEERING STRUCTURES.

The Baltimore Bridge Company have built within the year 1873, 55,000 ft. of bridges—nearly 10½ miles of iron structure.

Many different plans are represented in these bridges, including the Fink, Pratt, Howe, the Warren Girder, and other triangular systems not designated by any distinctive title.

Included in the above is the Varrugas Viaduct, on the Lima and Oroya Railroad, the iron pieces of which are 252 ft. high.

The Iron Bridge at Booneville, Mo.—From a letter of Mr. D. C. Brookes to the Chicago "Railway Review," we take the following:

Probably the most extraordinary "feat" in bridge building ever performed in this or any other country is that now approaching consummation in the construction of the bridge across the Missouri River, at this point, by the Missouri, Kansas & Texas Railway Company. Here is an iron truss bridge 1,638 ft.—or more than one-third of a mile—in length from centre to centre of abutments; resting on piers partly of stone and partly of iron pneumatic tubes, and having a draw with two openings of 160 ft. each in the clear—wholly completed (if finished, as is assured) by January 1st next, in the brief period of about *ten* months. This unexampled progress is due (not omitting, of course, to recognize the energy of one of the most enterprising of the great railway companies of the West, possessed of the ready money to command every facility and to improve every moment of time) to the facts that the topography and *regimen* of the impetuous current of the Missouri were now thoroughly understood in the light of previous successful attempts; that the best known, and, doubtless, best possible modes of sinking foundations, whether of stone or iron, through deep and shifting sands to the solid rock bed had been arrived at; and that the railway company availed itself of the services of engineers thoroughly experienced in every process required, seconded by the efforts of an organization (the American Bridge Company, of Chicago) whose history is peculiarly identified with bridge construction over the Missouri River. The work has been prosecuted under the immediate supervision of Mr. O. B. Gunn, the Chief Engineer of the Missouri, Kansas & Texas Railway Company; with William Sooy Smith as engineer of the bridge, and the American Bridge Company as the contractors for the work. In the months of October and November, 1870, General Smith made the preliminary surveys, and selected the location for the bridge. Work was not actually begun till Sept. 1872; and very little was done, except in the way of preparation, until the opening of the spring of 1873. From that time to the present, work has been literally "pushed,"—being carried on night and day, week in and week out, without even a Sabbath day's rest.

On the line chosen for the bridge a table of rock extends from the south bank (here quite precipitous) out under the stream 500 ft., with a depth of water thereon, at low water, of from 10 to 15 ft.; for the next 200 ft. the rock drops off to a depth of 33 ft. below low water; and from thence to the north bank to a depth of 54 ft. below low water. The width of the river at low water is 1,000 ft. and at high water 1,600 ft., and the total length of the superstructure is 1,639 ft. The location from bank to bank is 3,200 ft. Besides the main channel, there was in the natural state of the river a secondary channel of 1,000 ft. on the north side, with an island 700 ft. wide between. In locating the bridge it was decided to fill up the secondary channel, and also to fill in partly across the island, making a heavy dyke, thus—by entirely damming the secondary channel—throwing all the water into the main channel on the south side of the island. This dyke was completed about the 1st of January last, before the annual rise. The effect of the high water was to completely scour out the sand bar obstructing the main channel, greatly to the benefit of navigation; also to scour out the sand from off the rock, leaving it bare at (pivot) piers 1 and 2. The dyke, containing 125,000 cubic yards of earth, has its slopes thoroughly riveted with brush as at the St. Joseph Bridge)—no stone being used—to 4 ft. above high water. The water this year was the highest since 1867; yet no damage occurred to the dyke. The effect on the river has been to form a heavy natural dyke across the upper end of the slough, one mile above the bridge, and also across the lower end 1,000 ft. below the bridge, thus shutting the water off from the slough entirely.

The bridge consists of eight spans: 2 (fixed) of 248 ft. each; 3 do. of 225 ft. each; a draw span (two openings), having a total length of 363 ft., and an approach span on the north side of 84 ft., making a total length of 1,638 ft.

The following are the total quantities used in the substructure:

First class masonry, cubic yards	4,222
Concrete, cubic yards	2,354
Riprap, cubic yards	2,268
Earth embankment (approaches)	110,000
Timber (in feet board measure)	482,576
Pneumatic cylinders (lineal ft. 668) tons	600
Wooden piles (foundation of abutments), lineal feet	2,652
Wrought iron drift bolts, etc., lbs	60,606
Cast-iron braces, washers, etc., lbs	24,300

The eight spans composing the bridge are all of iron: Post diagonal truss—outside intersection; top chord, cast iron; bottom chord and ties, wrought iron. The assumed strength of the wrought iron is 60,000 lbs. per sq. in.; assumed strength of superstructure, 2,100 lbs. per lineal ft.; assumed weight of moving load, 2,500 lbs. per lineal ft. All the iron in the bridge is tested to double the estimated strain which it will receive beneath the maximum load; all materials used at a safety factor of 6.

ORDNANCE AND NAVAL.

The Russian Circular Ship.—The Russian circular iron-clad ship Popowka is a turret vessel, flat-bottomed, 97 ft. in diameter, and of 2,491 tons. Her draught of water is estimated at 12½ ft. The hull is to be protected by 7-in. armor, and the turret by 9-in. plates. The ship will be driven by six screws equidistant from each other, and each worked by 80-horse power engines, the whole motive power being 480-horse power. A ram-shaped beak forms the bow, and at the opposite extremity of the diameter a rudder-post and rudder is fixed. The armament is to be two 11-in. Krupp steel breech-loading guns, throwing 500 lbs. shot, and worked in a fixed turret. The object of this circular construction is of course to carry a more perfect armor protection on a comparatively light draught of water and small tonnage. The keel was laid at St. Petersburg, in May, 1871, and the vessel is expected to be ready for her steam trials in the course of this year. Much interest will be excited in this country as to the results of this experiment. We need hardly say that the idea of building a circular ship is by no means novel, but the possibility of attaining respectable speed has been always seriously doubted. On the other hand, with an equal thickness of armor the circular ship would be less burdened by the weight, and the difference of displacement might, it has been urged, be employed in extra engine power. This, however, has not been done in the Popowka. Unless the indicated horse-power be vastly greater than the nominal power given, we can hardly think she will attain a high speed. The Popowka is only 150 tons less tonnage than our own Hostpur, which has 600 horse-power engines, and though nearly double the beam of the Hostpur the circular ship has 120 horse-power less engine power. The fixed turret of the Hostpur has also been given up as a mere shell-trap with four large openings for the admission of projectiles; and we should imagine that the most favorable type of vessel for a revolving turret would be a circular ship. This detail may possibly be reconsidered before completion. Should the Popowka turn out even a partial success, the principle of circular iron-clads has so much to commend it, that the experiment may deserve repetition under more favorable conditions. The principle of diminishing the area of armor protection to ordinary broadside ships, in order to thicken the plates, is thought by many to have been carried far enough as regards the hull. The present reduced belts leave vital parts above and below them exposed to view in the most ordinary weather at sea. Shot-holes might easily be made immediately below or above the belts near the extremities, which, in the heave of a sea swell, would admit water very freely. The width of the belt cannot therefore be farther diminished with safety, and if the only object of a ship of war was to keep out shot, the circular ship would seem the most natural means of carrying the heaviest weight of armor on the smallest draught of water. That the Popowka may present advantages in the shallow waters of the Baltic, or in bombardments, or for coast defence purposes, is evident. But it does not at all follow that such a vessel could frequent the open sea, or take part in a general engagement with safety. It is, for example, obvious that the Popowka would be more easily rammed by a hostile ship than the Hostpur, for whereas the latter ship could only be destroyed by a ram striking her within a small angle of the perpendicular to either broadside, and could by a slight movement of her helm increase that angle rapidly to the safety arc, the Popowka is open to attack by rams on any diameter, and could be struck at right angles to the circular side at the point of impact, however the vessel was turned. The Popowka cannot, in fact, present her side at a safety angle to a ship which steers for her central turret; whereas the Hotspur is safe against rams for at least half the circle. If, in addition to this, we credit the Hostpur with higher speed, and reflect that the force of impact is represented by the difference between the speeds of the attacking ram and the attacked ship, the advantage on the side of the broadside ship in such a contest will be still more evident. On the other hand, the circular ship will have an apparent advantage in using her ram, in consequence of the great ease with which she can change her course, so as to present her beak to a vessel trying to avoid the attack. But this advantage is limited by the circumstance that the greater breadth of bow (if we may so call it) covers the action of the beak, and would necessitate an approach by a more direct path. This limitation of the angle of approach will be evident when it is reflected that the long lean bow of an ordinary ship admits of the beak being used freely at every perforating angle; while the circular ship is not only double the breadth, but carries that breadth almost up to the beak itself. The great advantages of the Popowka over the Hotspur will be 7 ft. less draught of water, an enormous gain in coast defence or coast attack, and probably in seaworthiness. This latter point is regarded by sailors as the first essential of a ship, and as more essential in vessels designed for the defence of stormy coasts, than in those intended to operate in the open sea. With 19 ft.

draught of water, shelter is denied to the Hostpur by most of our rivers, estuaries, and creeks. Land under the ice is a source of imminent danger in a storm when its harbors cannot be entered, for then the rocks to leeward rather than the ease of the ship governs the seamanship of the situation. A ship on a lee shore does not get so fair a chance of life as one in the mid-Atlantic. Yet the custom has arisen of classing every unseaworthy ship-of-war which is unhappily launched as a "coast defence" vessel, until unseaworthiness and coast defence have become synonymous terms. It is, indeed, worthy of Mr. Plimsoll's consideration, whether the proposed Act to prevent unseaworthy and overladen ships proceeding to sea ought not also to apply to the Royal Navy. If an unseaworthy and overladen ship may not carry a dozen men and a cargo of coals from Newcastle to Portsmouth, why should an unseaworthy and overladen ship-of-war be permitted to carry 150 men and a cargo of guns and armor from Portsmouth to Newcastle? Whether the Popowka will prove less unseaworty than so many of our low freeboard vessels is not, as regards the construction of circular ships for our own fleet, the least interesting point to be watched for in the coming trials. Whatever be the result, the Russian Government and its naval constructive advisers are to be congratulated on the boldness which dictates this courageous experiment. We trust that, having ventured upon this expensive proceeding, they will not emulate the inertia of our own Admiralty under like circumstances, but exhaustively investigate the several merits and demerits of circular ships; so that valuable experimental data may be accumulated under the guidance of scientific seamen, which shall lay the foundation of true knowledge on a subject long agitated, but of which little, if anything, is actually known.—*Iron.*

THE ORDNANCE REPORT ON RIFLES AND HEAVY ORDNANCE.—General Dyer, Chief of Ordnance, in addition to portions of the report already published in these columns, says: On the subject of small arms, in conformity with the provisions of the Act of June 6, 1872, appropriating $150,000 for the manufacture of arms at the national armory, a Board convened in New York city September 3, 1872, and concluded its labors May 5, 1873. After an exhaustive examination and trial during a session of months' duration, of over 100 arms, including those adopted by the first military powers of Europe, the Board resolved that the Board recommend that the Springfield breech-loading system be adopted for the military service of the United States, in accordance with the provisions of the Act of Congress approved June 6, 1872. The Springfield Arsenal is now engaged in the manufacture of rifles and carbines on the new model for the military service. Ten thousand of these arms will be supplied to the army for trial. The report says respecting heavy ordnance: The importance of the subject increases with the earnest and continued efforts on the part of all nations, not only to improve the quality of the guns, but in providing in quantities those that have given best results in experimental trials. It is not the part of wisdom to wait for ultimate perfection in gun constructions, which may never be attained, or for the first rumbling of approaching strife, when guns are needed in fortresses and not in foundries, to commence the tedious and costly work of construction. In the modern quick and decisive settlement of differences by the arbitrament of arms there is no time for preparation after the declaration of war, and a nation may sink beneath the powerful blows of a well armed adversary in less time than it takes to manufacture a single gun.—*Iron Age.*

BOOK NOTICES.

A TREATISE ON THE METHOD OF GOVERNMENT SURVEYING. By S. V. CLEVENGER, U. S. Deputy Surveyor. New York: D. Van Nostrand. (In Press.)

This work is designed to be a guide to the methods of surveying public lands, as prescribed by Congress and the Commissioner of the General Land Office.

The following table of contents will explain to what extent the author has discussed the practical details of the subject.

PART I.—Introduction—Initial Point—Principal Base—Principal Meridian Standard Parallel — Guide Meridian — Independent Meridian — Township True Lines and Randoms—Subdividing into Sections—Subdivisional Random Lines—Subdividing into Quarter Sections—Meandering Irregularities and Expedients.

PART II.—Triangulations—Traversing Meanders—Astronomy used in Surveying—Uses of Logarithms—Converging and Diverging—Vernier Reading.

PART III.—Vernier Compass—Solar Compass—Flagging—Chaining – Blazing—Corner Building—Witness Corners — Meander Corners — Blazing Trees or Objects – Bearing of Land or Water Objects — Closing Limits — Outfitting—Topography—Tablets—Field Notes.

PART IV.—Tables—Logarithms—Logarithmic Tangent and Sine Tables—Traverse Table—Natural Tangents – Convergencies – Length of Degrees of Longitude—Refractions – Equation of Time.

LIGHT SCIENCE FOR LEISURE HOURS (Second Series.) BY RICHARD A. PROCTOR, B. A. London, 1873. For sale by D. Van Nostrand. Price, $3.75.

This last book of Mr. Proctor's is in no way less interesting or instructive than those which have preceded it. It is better adapted to the comprehension of the general reader than the treatise on the Moon.

Mr. Proctor thinks out his conclusions so often and so intuitively, by aid of double integrals, that it must cost something of an effort to eliminate the higher mathematics from his astronomical essays. But one who has read only his articles for the standard periodicals would hardly suspect this; the most familiar and unmathematical illustrations are employed to elucidate difficult points in physics and astronomy, and used with rare success. The student who has read "Saturn and his System" knows something of Mr. Proctor's powers of analysis, and has learned to respect the opinions set forth, although the science is so light that it may be comprehended by the novel reader.

Of the present series, the chapters on "The Gulf Stream," "The Ever Widening World of Stars," "The Great Nebulæ in Orion," "Something Wrong with the Sun," and "News from Herschel's Planet," are worth the cost of the boook.

HOW TO BECOME A SUCCESSFUL ENGINEER. By BERNARD STUART. (Sixth Edition.) New York: D. Van Nostrand. Price, 50 cents.

The inquiry most frequently made by young men, at least the one with which we are most familiar, is, "What is the nccessary education for an engineer?" This the little book of Mr. Stuart answers quite clearly. And whether the inquiry refers to mechanical or civil engineering, the reply is equally explicit.

The several topics: The Education Preliminary to Practice—Special Education - Technical Education, Workshop and Workshop Practice—The Education of the Civil Engineer, are all exhanstively treated and will be found profitable reading even by the engineer of long practice.

FREE HAND DRAWING. A GUIDE TO ORNAMENTAL, FIGURE, AND LANDSCAPE DRAWING. By AN ART-STUDENT. New York: D. Van Nostrand. Price, 50 cents.

That this is the second edition is testimony to the value of this little book. It presents the rudiments of the art of drawing by familiar examples in a style not to be misunderstood by the merest tyro.

The separate topics are: Materials Employed in Drawing and how to Use Them—On Lines and how to Draw Them—On Shading—Concerning Lines and Shading with Applications of them to Simple Elementary Subjects—Sketching from Nature.

The illustrations of the progressive exercises are numerous and well executed.

THE BORDER-LAND OF SCIENCE. By R. A. PROCTOR, B. A. London, 1873. For sale by D. Van Nostrand. Price, $5.25.

Mr. Proctor has here collected a number of the popular papers on scientific topics contributed by him to the pages of the "Cornhill Magazine," where they have probably come under the notice of some of our readers. Mr. Proctor's specialty forms the subject of the major part of them; but one, at least, is within our own field, and particularly interesting to everybody at present: we allude to the "Few Words about Coal," in which the author, after an instructive sketch of the nature and origin of that useful mineral, proceeds to discuss the urgent question of our coal supply, so far as concerns the availability of the still untouched stores, as depending on the depth to which mining operations can be pushed. Accepting the dictum of the Commissioners on the Coal Supply, that 3,000 ft. is about the lowest depth at which, owing to the increase of temperature, coal can be worked, and that the quantity thus available must be reckoned at something less than 150,000,000 tons, he yet demurs to the conclusions arrived at by these officials, and by Messrs. Jevons and Hull, as to the probable rate of increase of consumption, holding that although for many years to come, the average rate may be expected to be fully equal to that at present observed, yet, before many years are passed, that rate (then higher than now) will be beginning to diminish, thenceforward returning towards its present rate, and passing eventually below it. And as the extension of the employment of coal for known uses has in several cases nearly approached a limit, a reduction in the rate of increase of consumption would, he maintains, not necessarily imply a falling off in the commercial and manufacturing prosperity of the country, but the reverse, just as though a merchant whose gains had been increasing by £1,000 a year should find them still increase by £900, £800, £700, until the increase settled down to some constant or nearly constant sum, such as £200. In this way he extends the period of exhaustion fixed by the Commissioners as less than 280 years, to a millennium, adding that "1,000 years of prosperity is a future which this nation might contemplate with satisfaction."

TREATISE ON PRACTICAL SOLID OR DESCRIPTIVE GEOMETRY. By W. TIMBRELL PIERCE, Architect. With eighty-five plates. London, 1873. For sale by D. Van Nostrand.

The author of this treatise is of opinion that a good text-book on the subject of Practical Solid Geometry is much wanted for English students; but, remenbering the many works on Geometry published during the last few years, we should scarcely have thought so. The present treatise embraces orthographic projection and perspective, or radial projection; and Mr. Pierce proposes in a future work to show the application of the subject to the several arts of construction. Having been lecturer on geometrical drawing at King's College, London, and at Harrow School, the competency of the author to deal with his subject is certain.—*Builder.*

SIKHIM, WITH HINTS ON MOUNTAIN AND JUNGLE WARFARE. By Colonel J. C. GAWLER, F. R. G. S. (London: E. Standford.) For sale by Van Nostrand. Price, $1.75.

This is a narrative of the Sikhim expedition under Colonal Gawler in 1860, which the gallant commander now publishes as a tribute to the heartiness, energy, and excellent conduct on the part of the officers and men, by means of which the compaign was brought to a successful and happy termination. A good part of the book consists of the official reports, published by permission of the Secretary of State for India; and in these and the connecting narrative will be found much that will be interesting to the general reader, and likely to prove useful to officers engaged in offensive operations in a similarly mountainous and densely wooded country. On a somewhat controverted point, of peculiar interest at the present time, Colonel Gawler speaks decisively and with the authority of success. He maintains that, properly directed, the disciplined and clothed British soldier is more than a match for the naked, undisciplined savage, in the bush, as well as in the open. "If the officer turns the discipline of his men to account, and dashes with them into the bush, the necessary fighting odds of the savage are at once reduced and the soldier is every moment on more even terms with him, to try him at close quarters, if he stand, which he never does." With respect to the advantage given by clothing in such circumstances, Colonel Gawler says that, when in command of Kaffirs, in active service, he found that "the unshod and half-clad savage has a very great dislike to leaving the footpath for the unbeaten bush, particularly if it be wet from rain or dew. It tears his skin, and thick though they be, the soles of his feet become spongy with wet and are soon penetrated by thorns." We quote the description of a novel species of suspension bridge across the river Teesta, which has an exceedingly elegant appearance in the illustrative engraving. The natives are said to construct a bridge with surprising speed and facility. The one in question consisted, first, of two parallel arches, 10 or 12 ft. apart, each constructed by securing a bundle of long bamboos (say 60 ft. long) by the butts in the bank on either side of the river and then bending them down across the river, making the thin ends overlap, and tying them fast; secondly, from the two arches so formed, are suspended bundles of bamboos, firmly lashed together, and also arched slightly, forming the footway. Two rails make all safe. It is described as far more comfortable than the ordinary cane suspension bridge, and easily practicable for horses and cattle.—*Iron.*

A MECHANICAL TEXT-BOOK; OR, INTRODUCTION TO THE STUDY OF MECHANICS AND ENGINEERING. By W. J. M. RANKINE, C. E., and E. F. BAMBER, C. E. London, 1873. For sale by Van Nostrand. Price, $3.50.

This text-book is primarily intended as an introduction to more abstruse works on the same subjects, in particular to those of Professor Rankine, which hold a very high rank. The matter is arranged in six divisions, the principles of cinematics, the theory of mechanism, the principles of statics, the theory of structures, the principles of kinetics, and the theory of machines, embracing the whole field of mechanics and engineering, the principles and practice of which are explained in a manner at once lucid and comprehensive. Mr. Bamber, whose name appears as the joint editor, lectured for Professor Rankine during his last illness, assisting him also in the preparation of this work. At the time of Mr. Rankine's death, its general scope and plan had been decided on, and 200 pages completed, and that plan has been implicitly followed out by the survivor.

THE GAS CONSUMER'S MANUAL, AND ON SETTING AND WORKING RETORTS. London. For sale by Van Nostrand. Price, 75 and 50 cents.

Are pamphlets on the subject of Gas and Gas making, by Mr. E. S. Cathels, C. E., of the Crystal Palace District Gas-Works, Montreal. In the first of these the writer considers the important question involved in the obtaining of good and cheap gas, and after succinctly stating the principles on which all improvements must be based, enters minutely into detail as to burners and their construction, the use of globes, governors, etc.; his conclusion being that the "London" self-regulating flat flame, or argand burner, with Sugg's albatine shades, may justly be characterized as the very triumph and luxury of gas-lighting. Mr. Cathels states in his preface that it is estimated that the number of deaths in the United States in 1872 from explosions of lamps (burning unrefined mineral oil, we presume), was 5,250, besides 20,000 persons maimed or otherwise injured. Second only in importance to gas-lighting, the writer considers cooking by gas. He maintains that this has advantages in convenience, cleanliness, and economy as great relatively in the case of the smallest family as the largest public institution if the gas be but properly burnt and carefully used; and describes and sketches a number of handy appliances for this end, concluding with plain instructions, doubtless necessary, in many instances, to householders as to the use of gas-meters. The other brochure is a reprint of a paper on the subject expressed in its title, read at the seventh annual session of the British Association of Gas Managers, in which Mr. Cathels, after repeating the history and explaining the principle of the operations referred to, describes and recommends a system of his own.

MISCELLANEOUS.

DEPOSITS IN BOILER FLUES.—Professor Hayes gives, in the "American Chemist," the following opinion regarding the formation of these deposits. They are of two kinds, both of which are capable of corroding the iron rapidly, especially when the boilers are heated and in operation. The most common one consists of soot (nearly pure carbon) saturated with pyroligneous acid, and contains a large proportion of iron if the deposit is an old one, or very little iron if it has been recently formed. The other has a basis of soot and fine coal ashes (silicate of alumina) filled with sulphur acids, and containing more or less iron, the quality depending on the age of the deposit. The pyroligneous deposits are always occasioned by want of judgment in kindling and managing the fires. The boilers being cold, the fires are generally started with wood, pyroligneous acid then distils over into the tubes, and, collecting with the soot already there from the first kindling fires, forms the nucleus for the deposits, which soon become permanent, and more dangerous every time wood is used in the fireplace afterward. The sulphur-acid deposits derive their acids from the coals used, but the basis material, holding these acids, is at first occasioned by cleaning or shaking the grates soon after adding fresh charges of coal. Fine ashes are thus driven into the flues at the opportune moment for them to become absorbents for the sulphur compounds distilling from the coals, and the corrosion of the iron follows rapidly after the formation of these deposits.

STEEL bars have been advocated in place of bells for churches and similar purposes. They produce a pure, distinct and melodious sound, and are said to be cheaper, lighter, and not so liable to crack as bells.

PROPORTIONS OF TALL CHIMNEY SHAFTS.—The following list, showing the rate of diminution and the proportion of base to height, in a number of large chimney shafts, may interest some of our readers. The figures are taken in some cases from the "Engineer's Pocket-Book" and similar works, and in other cases from the actual drawings of the shafts referred to. It is observable that the proportions of large chimneys vary considerably in different places. Local customs doubtless have their influence, but the special purposes in view in each case have, and ought to have, more influence still. It makes a great difference whether the shaft is to be used for an engine boiler, an iron furnace, or a range of kilns, and a flue that would answer perfectly well for one of these, might do very badly for either of the others.

NAME.	Outside diameter at base.	Height above ground.	Diminution of width in 10 ft. of height.	Number of diameters high.
	ft. in.	ft.	in.	
Townsend's Chemical Works, Glasgow	32 00	454	4¾	14 1-5th, about
S Rollox, Glasgow	40 6	432	7¼	10 5-8 "
Chemical Factory at Barmen. Prussia	18 00	331	2½	18 1-3 "
Chimney at Bradford, Yorkshire	20 00	300	4⅓	15 —
West Cumberland Iron Company, Workington (No. 1)	24 00	250	5	10 1-2 "
Dye Works, Hagen, Prussia	18 6	274	3⅓	14 6-7 "
Pontifex's Works, Isle of Dogs	20 6	228	6	11 1-8 "
Shell Foundry, Woolwich	16 9	224	5½	13 3-8 "
Messrs. Gostling's Northfleet (part fell)	22 00	220	6	10 —
West Cumberland Iron Company, Workington (No. 2)	23 00	200	5	8 2-3 "
Boring Mill, Woolwich	13 1	170	5⅛	13 —
Rocket Buildings, Woolwich	11 6	150	5⅝	13 —
Steam Engine at S. Ouen, France	10 8	132	5½	12 "
Saw Mill, Woolwich	10 6	130	5⅓	12 "
Paper Factory, Woolwich	10 3	120	5	11 3-4 "

The Sutcliff Gun.—On the afternoon of Monday, the 3d instant, the new Sutcliff gun, weighing in its rough state 72,000 lbs., was successfully cast at the West Point Foundry, and, being the most gigantic piece of ordnance ever cast here, has created considerable interest.

At its last session, Congress made an appropriation for the purpose of assisting American inventors in their experiments on heavy artillery. Mr. Sutcliff, whose name the gun bears, is one of the few gentlemen whose plans are being tested by the Government. He is only interested in the steel mechanism which is to be attached to this "preacher that speaks to the purpose," as Miles Standish would call him.

The gun is made of the finest iron (standing a pull of 30,000 to 35,000 lbs.), and brought here by Messrs. Paulding, Kemble & Co., for this express purpose. The casting is now 19 ft. long, but when finished will be only 15. It will then have a steel barrel 4 in. thick at the breech and 3 at the muzzle, with rifle bore, and weigh 45,000 lbs. The ball will be 9 in. in diameter, and weigh about 250 lbs.

The mould was made a week ago, and at the time of casting was as hard as a sun-dried brick. It was so situated that the iron from two large furnaces could be run directly into it by means of troughs. The core is a cast-iron tube, wound with rope and covered with sand. This was filled with water the moment the metal was run in the mould. Twelve and a half minutes were occupied in casting, and the water, which was being forced through the core at the rate of 25 gallons per min., was raised from 38 to 51 deg. The core will be kept full of water 12 hours, when the iron will be sufficiently set to allow its removal. The water will then be exhausted, and as soon as the rope burns from its outside, tackling will be attached and the core withdrawn. Then Rodman's celebrated process will be kept up for six days. The bore being always full of water, of course the contraction from the inside goes on more rapidly than from without, and the desired strength is thus obtained. The portion next the water is first contracted by cooling; the part next cooled, contracts, and binds the first, as it were, like a band on the inside. The next layer acts similarly, and so on till all is cooled, each part successively binding that within till all is held with great tenacity. Eight days will be required to cool this monster, and at a cost of about $15,000.—*Iron Age.*

Riehle's Testing Machine.—Messrs. Reihle Bros., of the Philadelphia Scale and Testing Machine Works, have made some interesting tests of manilla rope, the results of which are important to many classes of our readers. The strength of the several sizes tested is shown as follows:

	Wt. lbs.
6 thread	625
9 "	950
12 "	1,375
15 "	1,800
18 "	2,250
1¼ inch.	2,750
1½ "	3,250
2 "	4,100
2¼ "	4,250
2½ "	4,750
2¾ "	7.375
3 "	8,000
3¼ "	9 750
3½ "	11,750
3¾ "	13,500
4 "	16,750

The above tests were made December 23, 1872, on one of Riehle Bros. patented "U. S. Standard Testing Machines," for Messrs. Edward H. Fitler & Co., Philadelphia, and can be relied upon as correct, as they were made very carefully, and upon the machine that tests were made for the United States Navy Department.—*Iron Age.*

VAN NOSTRAND'S
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No. LXII.—FEBRUARY, 1874.—Vol. X.

THEORY OF ARCHES.

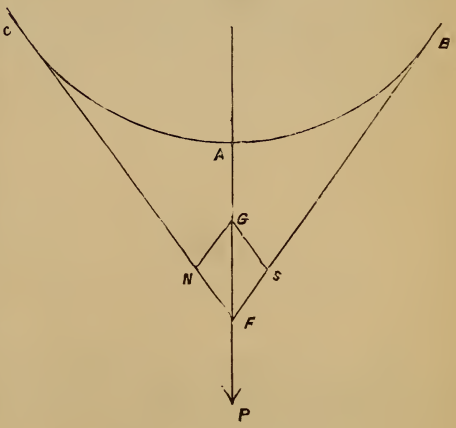
By Prof. W. ALLAN, Washington and Lee University, Lexington, Va.

The following is an amplification and explanation of Professor Rankine's chapters on this subject.

Perhaps the clearest way of developing the "Theory of Arches" is to begin with the consideration of the forces which act upon a suspended chain or cord. The force in the chain or cord is just the opposite of that upon an arch—that is—it is *tension* instead of *compression*, but the relations between the "external" and "internal" forces, or what is the same, between the loads and the resistances they produce, are strictly analogous.

Let C A B (Fig. 1) be a cord suspended at C and B and loaded in any manner over its whole length. Consider the forces acting on this cord. Suppose it attached to a hook at B and to another at C. A cord without stiffness cannot exert a pull except in the direction of its length: therefore the "pulls" in the rope at C and B, and exerted at these points on the suspending hooks, must be in the direction of the tangents at those points. The load is supposed to be distributed over the cord, but we may find its resultant. Let P be this resultant and P F its direction. The *three* forces, viz.: the pulls at C and B, and the resultant of the load, P, are all in the same vertical plane; they are the only forces acting on the cord; and as they are in equilibrium, the *directions of these three forces must meet in one point*, and the forces themselves *must be proportional to the three sides of a triangle drawn parallel to their directions*. G N F (Fig. 1) is such a triangle. The known directions of the pulls at B and C, and of P, give us the angles in this triangle; and if we know also the magnitude of the load P, represented by the line G F, we can determine that of the pulls at B and C. For

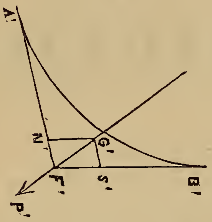
Fig. 1.



$$(\text{Pull at } B = GN) : GF :: \sin GFN : \sin GNF.$$
$$(\text{Pull at } C = NF) : GF :: \sin NGF : \sin GNF.$$

The analysis we have made for the whole cord may be applied to any part of it. Thus, if we consider any arc B′ A′ (Fig. 2) of the cord, and the load on that arc, we have three forces in the same plane in equilibrium. For at A′ and B′ the other parts of the cord may be replaced by two hooks, and the pulls on these hooks, exerted by the cord at A′ and B′, will be, as before, in the direction of the tangents at those points. The resultant P′ of the load on A′ B′ must pass through the point of intersection of the tangents, and if the direction of that resultant be as indicated in the figure, then G′ N′ F′ will be the triangle of forces.

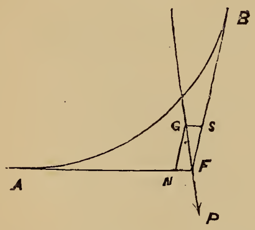
Fig. 2.



The principles above explained enable us to calculate the "pulls" at all points of a loaded chain or cord, and consequently to fix *its size and strength to bear* a given load; or to determine the *amount, distribution, and direction of the load* necessary to produce assumed "pulls" in a cord of a given shape.

Thus suppose in the half of the loaded cord of (Fig. 1) we draw the tangents at A and B (as is done in Fig. 3), the resultant of the load P *must* pass through F, the point of intersection of the tangents. If the direction and amount of P be known, lay off F G to represent it. Then, as above explained,

Fig. 3.



N F = pull at A

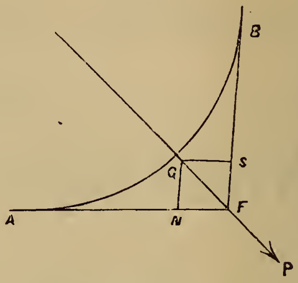
and

N G = pull at B.

Suppose, on the other hand, we assume the pulls at A and B to be equal, we lay off on the two tangents (Fig. 4), equal lengths, F S and F N, to represent these equal pulls, and upon them construct a parallelogram. Then F G gives the magnitude and direction of the resultant of the load that must be put on the cord to produce the given pulls.

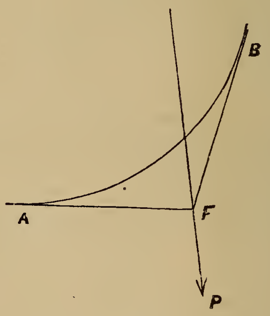
A cord is in *equilibrium* when it is balanced under the load applied. Change the distribution of the load and the cord at once changes shape and assumes the form necessary to equilibrium under the new load.

Fig. 4.



Thus, if P (Fig. 5) equals the direction of the resultant of the new load on the cord from the horizontal point A to the point of support B, draw the tangent A F, until it meets the direction of the load P, at F; then draw F B. The cord A B will have so changed its form that F B (Fig. 5) will now be the direction of the tangent at B.

Fig. 5.



FORMS OF CORDS UNDER VARIOUS LOADS.

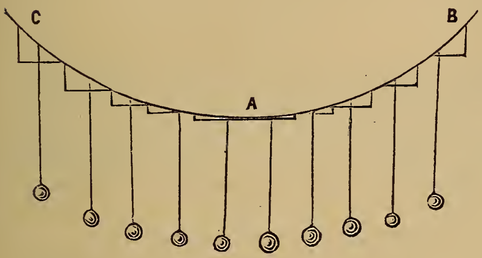
Let us now investigate the various curves which a cord will assume under different distributions of the load.

Case I. Suppose the load to be altogether *vertical*, and to be distributed *uniformly* along the *horizontal.*

Let *equal* weights be hung, for instance, along a cord C B (Fig. 6) so that the *horizontal* distance between the threads by which the weights are suspended shall be everywhere equal. Or, draw little elementary triangles along the curve, so that the *bases* of all these little triangles shall be equal, and let the threads holding the weights cut the middle of these bases.

Then each weight may be considered as the resultant of the load on the element of the curve which constitutes the hypothenuse of the little triangle to which it is attached. Such a load is *vertical* and is *uniformly distributed along the horizontal.*

FIG. 6.

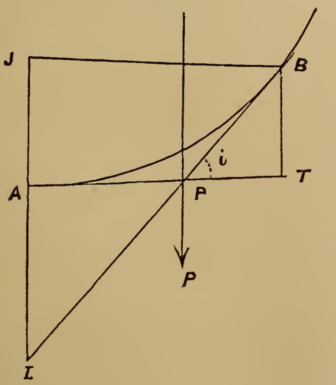


To determine the curve of the cord. Obtain the resultant of the load between the horizontal point A and the point B (Fig. 7). This resultant, as the little forces are all parallel, is equal to the sum of them, and it is vertical in direction. It will also evidently bisect A T. Draw it, and from its point of intersection with A T, draw the line F B, which, as has been shown, must be tangent at B. Prolong B F to I, then the subtangent I J is seen to be bisected at the vertex A of the curve. Hence the curve C B is a *parabola.*

The triangle B F T has its sides parallel to the forces acting on the half cord A B; so that if B T be taken to represent P,

B F = pull at B
F T = pull at A.

FIG. 7.



Let T = equal tension at any point along the cord.
H = value of T at the horizontal point A, or the "horizontal pull" on the cord.
i = inclination of the tangent at any point to the horizontal.

Then as the arc A B (Fig. 7) may stand for any part of the curve counting from the horizontal point A towards one of the points of suspension, we have the following general equations from the triangle B F T:

$$T^2 = P^2 + H^2 \qquad (1.)$$

$$\text{Tan } i = \frac{P}{4} = \frac{p\,x}{H} = \frac{d\,y}{d\,x} \qquad (2.)$$

(p being = the load per unit of horizontal distance, A the origin of co-ordinates, A T = axis of X and A J = axis of y).

From equations (1) and (2) we can solve three problems.

1. Given the *curve*, and the *load*, to find T and H.
2. Given the *curve*, and T and H, to find P.
3. Given the *load*, and T and H, to find the curve.

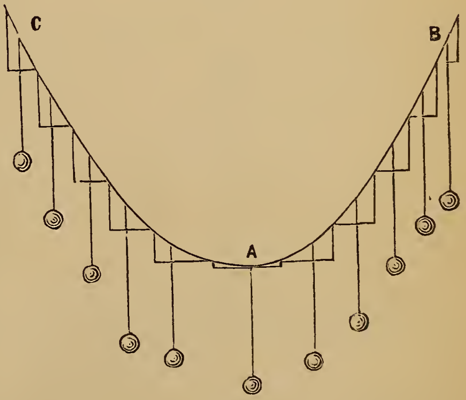
For a full discussion of this case, see Rankine's "Civil Engineering."

Such a distribution of the load as we have discussed in the above case, is approximated to in suspension bridges, and sometimes in wood, iron, or steel arches, but not usually in stone or brick ones.

Case II. Let the load still be *vertical*, but distributed *uniformly along the curve.*

That is, divide the arc C A B (Fig. 8) into elements each of a unit in length; then the load on these elements is constant throughout. It is easily seen that such a load is not, as in the last case, uniform along the *horizontal*, for the *basis* of the little triangles of which the *hypothenuses* are now equal, diminish in extent as we go from A towards B or C. A chain of uni-

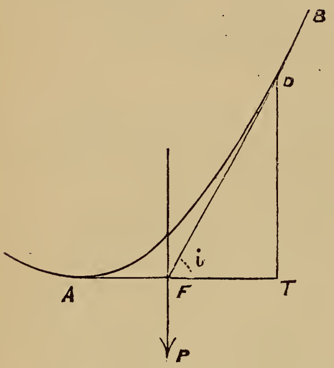
FIG. 8.



form material and cross-section and acted on by nothing but its own weight, is in the condition described, and, as is well known, the curve assumed by it is the "common catenary."

Let p = weight of a unit's length of the cord, then if $p\,m$ = horizontal pull on the cord at A = H, m is called the *modulus* of the *catenary*, and represents the length of cord of the same kind as C B, the weight of which would equal the pull at A. The weight on A B = P = $p\,s$ when s = length of cord A B.

Fig. 9.



The triangle of forces for any arc A D (Fig. 9) can be found as before, by drawing the tangents at A and D, and the line representing the force P vertically through their intersections. The triangle D F T will represent the forces; D T being P $= p\,s$, and F T = H $= p\,m$, and D F = T = tension at D. Then

$$T^2 = H^2 + P^2 = p^2\,m^2 + p^2\,s^2 = p^2\,(s^2+m^2) \quad (3.)$$

$$\text{Tan } i = \frac{D\,T}{F\,T} = \frac{p\,s}{p\,m} = \frac{s}{m} = \frac{d\,y}{d\,x} \quad (4.)$$

From the differential equation

$$\frac{d\,y}{d\,x} = \frac{s}{m}$$

we obtain the linear equation of the curve. In doing so it is most convenient to take the origin at a point O, whose distance below the vertex A is $= m$. The line Q O X (Fig. 10) is called the *directrix* of the catenary.

The equations of the catenary are

$$s = \frac{m}{2}\left\{ E^{\frac{x}{m}} - E^{-\frac{x}{m}} \right\} = \sqrt{y^2+m^2} = \text{length of arc.} \quad (5.)$$

$$y = \frac{m}{2}\left\{ E^{\frac{x}{m}} + E^{-\frac{x}{m}} \right\} = \sqrt{s^2+m^2} \quad (6.)$$

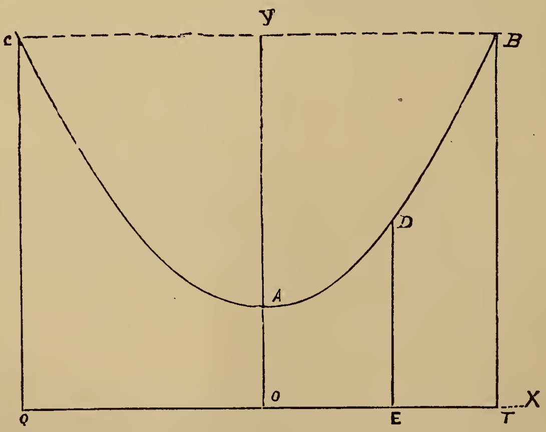
$$x = m.\ \text{hy. log.} \left\{ \frac{1}{\frac{y}{m} + \sqrt{\frac{y^2}{m^3} - 1}} \right\} \quad (7.)$$

$$\text{Area A O E D} = \int y\,d\,x = m\,s \quad (8.)$$

$$\text{Tan } i = \frac{s}{m} = \tfrac{1}{2}\left\{ E^{\frac{x}{m}} = E^{-\frac{x}{m}} \right\} \quad (9.)$$

$$\text{Radius of curv.} = C = \frac{y^2}{m^2} = \frac{m^2+s^2}{m} \quad (10.)$$

Fig. 10.



Since the area A O E D $= m\,s$, and m = a constant, the area varies as s. But the load on the arc A D ($=p\,s$) also varies as s, since p is constant. Hence a convenient mode of representing the load on any arc, A D. Suppose a sheet of metal C Q T B A C (Fig. 10), bounded below by the "directrix," Q T, to be suspended from the curve. Let the weight of this metal corresponding to m units of its surface be $= p$. That is, let

$$w\,m = p, \text{ or } w = \frac{p}{m}.$$

The weight of a strip a *unit in breadth* extending from A to O is then $= p =$ the weight of a unit's length of the cord. Then the part of the sheet A O D E whose weight $= w m s = p s$, represents the weight P on the arc A D. So A O B T represents the weight on A B, and C Q T B the whole weight on C A B. In the horizontal pull at A we have

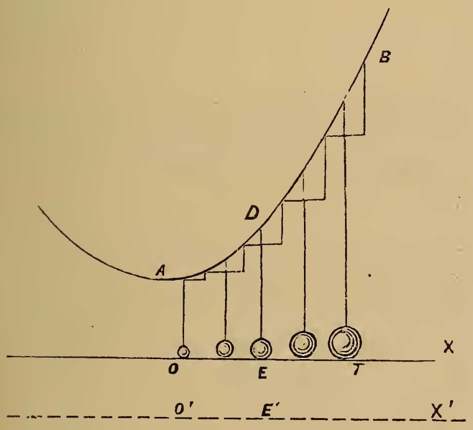
$$\mathrm{H} = p m = w m^2 \qquad (11.)$$

and at any point D

$$\mathrm{T} = \sqrt{\tfrac{1}{4}^2 + \mathrm{P}^2} = p\sqrt{s^2 + m^2} = p y = w m y. \qquad (12,)$$

The property above explained may be illustrated in another way.

FIG. 11.



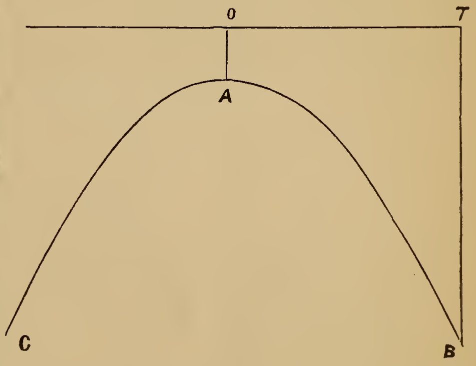
Constant on A B (Fig. 11) a series of little triangles with all their *bases* equal. Let the weights of the little arcs constituting the hypothenuses of these triangles be represented by balls suspended by threads from the middle of each little arc. Take the length of the thread corresponding to the ball at A as $= m$; make the lengths of all the threads proportional to the weights of the balls hung to them; then the lower ends of these lines will all be on the directrix O X. That is, the *intensity* of the load on a catenary along the horizontal line weight on a unit of horizontal distance) varies as the *ordinates* of the catenary, when those ordinates are measured from the directrix.

It makes no difference in the form of the curve A B (Fig. 11), to increase or diminish the weights provided the *proportion* among them is preserved. Thus we may assume the cord and the sheet C Q T B (Fig 10), to be of a different material in which a unit's length of the cord shall in weight $= p'$, and the weight of the sheet per unit of surface shall $= w'$, and A B will be unchanged. Note, however, that we cannot change the depth A O of the sheet (Fig. 10), nor the length of the lines (Fig. 11), without changing the curve, for if the lines ended in O′ X′ for instance, instead of O X, then $\frac{\mathrm{A\,O}}{\mathrm{D\,E}}$ would *not* be equal to $\frac{\mathrm{A\,O'}}{\mathrm{D\,E'}}$.

Hence, the *modulus* ($m =$ A O) fixes the catenary, or if we assume the catenary, this determines the modulus. Thus if we assume three points, B, A, C (Fig. 10), on the catenary the distance A O is thereby determined; and if we assume A O and the point A we cannot generally assume B and C.

This often interferes with the use of the "common catenary" in the building of arches (in which case the curve is inverted, the metal sheet A O T D is replaced by a wall of uniform material, and the tension on its cord, C B (Fig. 10), is replaced by a thrust along C A B (Fig. 12). For we are often compelled to make the curve pass through three points, while yet the value of A O is fixed.

FIG. 12.



But this difficulty may be obviated by the use of the *transformed catenary*, which we will now discuss.

Case III. By the principle of *Parallel Projections*, if any cord or arched rib is balanced under a system of forces which are represented in the figure by lines, and a *parallel projection* be made of the curve of the cord or rib and of the lines representing the forces, then the new curve will represent a cord or rib that will be balanced under the forces represented by the new lines.

Imagine a cylindrical surface constructed upon C Q T B A C (Fig. 10) as a base. To simplify matters, suppose the elements of the cylinder to be perpendicular to the plane of the base. Cut this cylinder by a plane inclined to the base, and we shall get a "Transformed Catenary," and the shape of the sheet of metal under which it will be balanced; for the new curve and surface cut out by the inclined plane are the *parallel projections* of the curve C A B and the surface C Q T B A C (Fig. 10). Let this inclined plane be so placed that it shall intersect the plane of the base in the straight line C B (Fig. 10) or in one parallel to it. Then all horizontal lines (or those parallel to C B or Q T) will be unchanged in length in the parallel projection, while all vertical lines (those parallel to A O, etc.) will be lengthened in a constant ratio whose magnitude will depend upon the inclination of the cutting plane. Make a vertical section of the cylinder on the line O Y. Then if the cutting plane passes though C B we get the triangle O U Y (Fig. 13*a*) cut out of the wedge to which the cylinder reduces in this case. In the triangle U V is the ordinate of the vertex of the *transformed catenary* corresponding to O A in the *common catenary*, and all lines parallel to U V are evidently increased over the corresponding ones of which they are the parallel projections, in the same ratio that U V exceeds O A. Laid down in the same plane the two curves are C A B and C′ A′ B′ (Fig. 13 *b*).

Fig 13 (*a*).

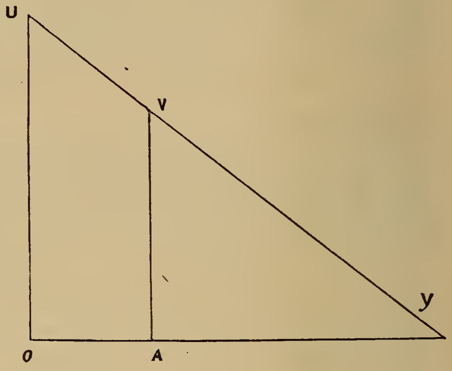
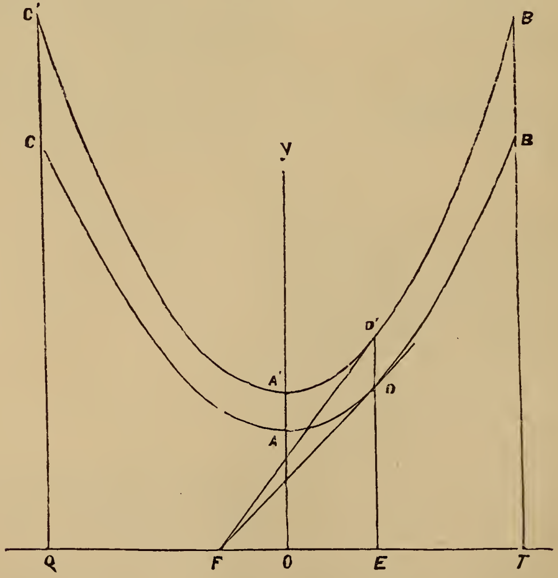


Fig. 13 (*b*).



It is easy to pass from a given catenary to a transformed catenary whose ordinates shall be *shorter* instead of *longer* than those of the given curve, by erecting an oblique cylinder on the given catenary and surface C Q T B, and cutting it by a plane less oblique than the base. So too, the horizontal dimensions can be changed instead of the vertical, by making the cutting plane meet the base in a line parallel to O Y, instead of in one parallel to Q T.

The equations of the curve C′ A′ B′ (Fig.

13 *b*,) are thus obtained. The *abscissas* are the same as those in C A B, but the ordinates are changed, so that (if y' = general ordinate of C′ A′ B′ and $y_o{}'$ = A′ O, the ordinate at the vertex A′).

$$y' : y : : A' O : A O : : y_o{}' : m.$$

$$\therefore y' = \frac{y_0}{m} . y \text{ or } y = y' \frac{m}{y_0}$$

In the equations of the common catenary substitute y' for y and we have the equations of C′ A′ B′.

From equation (6)

$$\frac{m}{y_0} . y^1 = \frac{m}{2} \left\{ E^{\frac{x}{m}} + E^{-\frac{x}{m}} \right\}$$

$$\therefore y' = \frac{y_0}{2} \left\{ E^{\frac{x}{m}} + E^{-\frac{x}{m}} \right\} \qquad (13.)$$

So equation (7) becomes

$$x = m \text{ hy. log.} \left\{ \frac{1}{\frac{y^1}{y_0} + \sqrt{\frac{y'^2}{y_0{}^2} - 1}} \right\} \qquad (14.)$$

So equation (8) or are a A′ O E D′.

$$= \int y' \, d\, x = \frac{m\, y_0}{2} \left\{ E^{\frac{x}{m}} - E^{-\frac{x}{m}} \right\} \qquad (15.)$$

etc., etc., etc.

The "triangle of forces" F E D (Fig. 13), for any arc A D of the catenary, becomes F E D′ for the arc A′ D′ of the transformed catenary—that is—since the horizontal lines—forces are unchanged.

$$\text{Tension at vertex } A' = H' = H = w\, m^2 \qquad (16.)$$

Load on A′ D′ is increased in ratio of A′ O to A O or of D′ E to D E.

$$\therefore P' = P . \frac{D' E}{D E} = P . \frac{y_0}{m} \qquad (17.)$$

(D′ E represents this load.)

Then tension at D′ is

$$T' = \sqrt{P'^2 + 4^2} \qquad (18.)$$

and

$$\text{Tan } i = \frac{d\, y'}{d\, x} = \frac{y_0}{2\, m} \left\{ E^{\frac{x}{m}} - E^{-\frac{x}{m}} \right\} \qquad (19.)$$

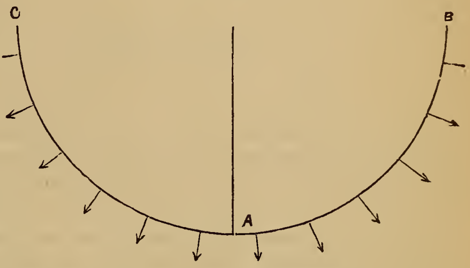
In this curve we can assume the directrix Q T, the distance A′ O (= y_o) and also the points B′ and C′. These quantities assumed, we determine *m* (the modulus of the corresponding common catenary) from equation (14), and then by equation (13) find points of the transformed catenary.

From equations (18) and (19) we can solve three problems similar to those given under the head of Case I.

Case IV. So far we have discussed the forms of cords under loads *parallel* and altogether *vertical.* Let us take up the cases of loads varying in direction.

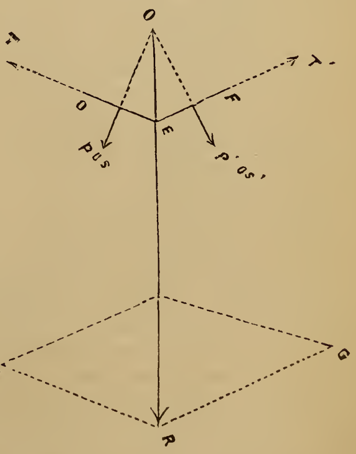
Suppose (as Case IV.) that the load be *uniform* and *normal* at *every point* to the cord. Such a load is represented in (Fig. 14), the load on each element $d\ s$ of the curve being constant and perpendicular to it.

FIG. 14.



It is first to be noted that the pull or tension on a cord under *any* load which is *everywhere normal* to it, must be *constant.* That is, the pull along the cord at A and B, and at all other points, is one and the same. That the tension at B in the cases previously discussed is greater than at A, is due to the fact that the elements of the load between A and B have in those cases *tangential* components, which go to change the value of the pull along the cord. But in the present case, the load being *everywhere* normal, there are no such tangential components, and therefore the "pull" does not change.

FIG. 15.



Take any two adjoining elements of the cord $d\ s$ (= D E, Fig. 15) and $d\ s'$ (= E F, Fig. 15), each of such length as to correspond to equal elements of the load. The little loads on these lines we will represent by $p\ d\ s$, and $p'\ d\ s'$. Note, that unless the load be uniform all around the cord, $d\ s$ will not be equal to $d\ s'$. The equal loads $p\ d\ s$ and $p'\ d\ s'$ being normal respectively to D E and E F, their resultant which lies in the direction O R (Fig. 15) bisects the angle between $p\ d\ s$ and $p'\ d\ s'$, and also the angle D E F between $d\ s$ and $d\ s'$, which last is the angle between the direction of the pulls T and T′ on the cord at D F. Hence the parallelogram of forces (as shown at R) will be a rhombus, or

$$NR = T = RG = T'$$

(To be continued.)

THE DRAINAGE OF SMALL TOWNS.*

From "The Building News."

In his introductory remarks, Mr. Whitaker said he attributed in a great measure the slow progress made in the sanitary improvement of our towns, and the fearful delays that continually occurred, to the disgraceful apathy, combined with etiquette and routine that existed at headquarters, as well as to the ignorance, obstinacy, and penuriousness of local boards and sewer authorities. The Minister or the Member of Parliament brought forward a bill that was full of good intentions, but it dared not attack anything in the shape of a "vested interest" or its fate was sealed. Witness the Public Health Act of last year. Its most potent clauses had all to be thrown overboard in order that the bill might pass. In individual cases, the endless correspondence, forms and stipulations, tended so much to delay, that what would be done by a private firm in a few days, took months of official time to accomplish. Mr. Whitaker instanced the case of a town which was visited twice by a medical and once by an engineering inspector of the Government, over three years ago, and pronounced to be in a disgustingly foul and unhealthy state. A system of drainage and water supply was ordered to be immediately carried out; but by a cunning method of working the cumbrous machinery, both central and local, which was provided, the Obstructives managed to have their way and nothing had yet been done. Other such cases might be instanced, until it would almost seem that Acts of Parliament hindered rather than promoted sanitary work. The delays and obstructions which arose were too readily taken advantage of by the ignorant and prejudiced vestrymen. Mr. Whitaker did not deprecate the principle of a central authority, for he believed that it was only by means of the compulsory powers of a Government Board that the improvement of the sanitary condition of the country would ever be effected. It was all very well to advocate local self-government, and rail at centralization; but until sanitary authorities were educated sufficiently to appreciate the value of sanitary measures, they must be led or driven by some power wiser than themselves. Passing over the consideration of the various processes of dealing with sewage, which have been so often discussed—the cesspool, pail, dry-earth and water-closet systems; the Native Guano, Phosphate Guano, and other chemical processes; irrigation, intermittent filtration, etc., which were all treated of in the voluminous Reports of the Rivers Pollution Commissioners, Mr. Whitaker remarked that the sewers proper of any town could be laid out in an endless variety of ways, often, even, differently in the same town, their position and direction depending almost entirely on the levels of the streets under which they passed, and the situations of the valleys, rivers, or other adjacent watercourses. Sewers having to pass over or under rivers often materially influenced the general laying-out of the system adopted, but the most important matter to be considered by the engineer, in nine cases out of ten, was the position of the outfall, or locality of the ultimate discharge of the sewage before its final disposal. The laying-out the sewers of a town was a comparatively easy matter, though of course it should always receive most careful attention, as from the number of the town sewers their judicious arrangement must materially affect the cost of any work of town drainage. The determination of the position of the outfall was

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*A paper read before the Civil and Mechanical Engineers' Society, by Mr. C. W. Whitaker.

often a matter of the greatest difficulty, and should never be settled upon without grave consideration and a thorough investigation of the locality. Time was not wasted, but well-spent, if many days or even weeks were occupied in arriving at a satisfactory solution of the difficulty. Available sites in the neighborhood should be visited, their situation with respect to the town considered, the direction of future building sites, the levels, soils, and surface formation inquired into, among various other matters, differing according to circumstances. In some cases the outfall would necessarily be far distant; sometimes it might be close to the town. At times the sewage might be conveyed away by gravitation; at others this was impossible, and pumping had to be resorted to. Obstructions and difficulties of various kinds would present themselves from time to time, and would have to be overcome by the tact and judgment of the engineer. With regard to the surface drainage, the author was of opinion that, as a rule, it was advisable to admit no waters—other than sewage waters for flushing—into the sewers. Generally, old drains and watercourses might be made available as carriers of rainfall to the natural outfall, and where not available new drains should be provided for the purpose. Where pumping was required this separation became almost a necessity. True, we had an example to the contrary at our doors; but sanitary engineering was a progressive science, and without describing in detail the results of working of the Metropolitan Main Drainage, he ventured to say that the engineers who laid out that system would never have designed it as it is, had they known what they have since learned. He ventured to predict that at no very distant day these very sewers would be used for sewage only, a new system of drains being constructed for the surface water, etc. With respect to the question of the sizes of sewers for small towns, it might safely be said that pipe sewers might for the most part be made available in all cases up to 10,000 inhabitants. He had never had the courage to propose in any street a pipe sewer of less diameter than 6 in., though he saw no reason why, when the gradients were good, 4 in., or even 3 in. pipes should not be laid down. He was inclined to think that in most towns the pipe sewers were constructed far larger than they need be if properly laid. In many cases the sum available for the work would not permit of sufficient proper supervision to insure the laying and jointing of every pipe perfectly firm and true. Nor was it possible to pick and select the good pipes and discard the bad ones, so as to insure perfect success. It might be asked—"Why not, if your specification is properly drawn up?" There were many reasons why it was difficult to carry out the letter of a specification in such instances. In small towns these works were usually let to the man who sent in the lowest tender, when, if he had respectable sureties, no amount of remonstrance from the engineer would avail to cause the man who really sent a respectably-priced tender to be chosen. The lowest tender got the job, and the contractor could not possibly do the work without losing money, unless he got his materials cheaply. The best pipe makers would not supply him without a considerable moiety of the cost being paid before delivery of the pipes. This he could not do, as he generally had to scramble on to the first instalment before he could pay anybody. Therefore he had to go to some second-rate maker who would give him credit for the pipes. If the engineer was a Shylock, and would have his bond, the contractor appealed to the Board, who, not knowing or not appreciating the difference between a good pipe and a bad one, let the man off, and allowed twisted, oval, or any sort of defective pipes to be laid. Another obstacle to laying out a system of pipe-sewers of sizes more nearly theoretically correct than was usually the case, consisted in the large differences in the sizes of the pipes as they had now become established by the pipe makers. There were pipes of 4 in., 6 in., 9 in., 12 in., 15 in., and 18 in. diameter, representing areas respectively as 16 to 36, 81, 144, 225, and 324. Mr. Whitaker said that what he should like to see done, and what he had often wished to have the opportunity of carrying out, was to have pipes made by the best makers (say Doulton), of small size (for the larger sizes were so difficult to make perfectly true), laid by good workmen, and well bedded and packed in their places, and with clean and smooth cement joints to each. And, in addition, he would like to have 5 in., 7 in., 8 in., 10 in., 11 in., 13 in., and 14 in. pipes, so that he could lay down a sewer of the capacity it ought to be (according to the inclination) to act as a carrier for the maximum quantity of sewage that its drainage area and population could ever bring to pass through it. But he was afraid that the manufacturers would not countenance the innovation as to the smaller gradations in the sizes of pipes, and pipes of these sizes would be charged treble or quadruple their real value, as a "purpose-made article." Mr. Whitaker then proceeded to give an account of the drainage works carried out from the plans of Mr. Perrett and himself in the small town of Uppingham, in the county of Rutland. These works consisted of an intercepting pipe-sewer about a mile in length, with short branches, air shafts, ventilators, descending shafts, etc., and a short piece of outfall pipe-sewer leading to the settling tanks, etc., at the fields laid out for irrigation. The total cost was estimated, at the time the plans were approved (viz., August, 1871), at £12,000; but the Board preferred (as such Boards usually did) to do the thing piecemeal, and let the drainage be done first. The tender for this part of the works was let in March, 1872, for £596—the lowest tender. Some extra works brought the total cost of this part of the scheme up to £657. About 50 acres east of the town were found to be available for irrigation, but of these it was proposed to lay out only 25 until the entire house drainage should become connected with the main sewer, and cesspools abolished. The area ultimately laid out was, however, only 15 acres. In that portion of the land nearest the tanks there was a very light soil overlying a loose stratified rock—very hard grit, called "Kale" in the locality. Further on this dipped, and was overlaid for a considerable depth by a stiff blue clay. The entire area of the land was laid with 3 in. and 4 in. subsoil drains, running north and south, 30 ft. apart, at depths varying from 2 ft. to 4 ft., and in some places 5 ft. or 6 ft. These were connected with a 6 in drain at the bottom, delivering the effluent water, after passing over and through the soil, into the brook. The surface of the land was laid with half-round 9 in. tile carriers, in lines about 50 ft. or 60 ft. apart. At the end of the outfall there was a small pit or chamber, with two wooden penstocks movable by hand, to turn the sewage into either tank. The tanks were in duplicate, the one being cleared out while the other was filling. They were built of 14 in. brickwork with 4½ in. brick-on-edge paved floor laid on about 12 in. of Portland cement concrete, the whole interior surface being rendered ¾ in. thick with Portland cement and sand in the proportions of 2 to 1. At the further end of the tanks a shed was built, with paved and rendered floor similar to those of the tanks. Here were carted ashes, street-sweepings, dry earth, etc., and when the liquid sewage had run off on to the land, the solid residuum was passed through an opening in the end wall of the tanks on to the floor of the shed, and mixed with the ashes, etc., the mixture being used as a top-dressing for the land above the tanks. A special arrangement of cast-iron vertical telescopic pipes was adopted to insure the equable flow of the sewage from the tanks. In each tank there were three vertical screens or strainers to collect as much of the solid matter as possible, though the greater part sank to the bottom in the form of thick black mud. The ordinary discharge of sewage amounted to about 6,000 gallons every 24 hours, but a large majority of the houses in the town were not yet connected with the drains. The application of the sewage to the land had greatly increased the soil's power of production. As carried out, the total cost of the works had been £1,770, made up of the following items:—Drainage, £657; supervision of ditto, £73; disposal of sewage, including tanks, shed, and laying out land, etc., £860; supervision of ditto, £60; and engineering charges and expenses, £120. In order to complete the sewerage system throughout the town, and make the remaining portion of the area proposed for irrigation suitable for the reception of the sewage, a further sum of about £1,200 would have to be expended, making an ultimate total of £2,970 as the probable cost of the entire work of town drainage and sewage disposal. There were portions of the irrigation contract that could not be estimated on as to amount, such as the number of the carriers required, the subsoil drains, and trimming the surface, etc. These items of variable work were therefore tendered for at per yard, as follows:—Excavation and trimming surface of ground, at 7d. per yard cube; 9 in. half-round tile carriers, at 1s. 7d. per yard run, laid; 3 in. subsoil drains laid complete, at an average depth of 3 ft., including filling-in and every expense, 7½d. per yard run; 4 in. ditto, ditto, 9½d. per yard run; 6 in. ditto, ditto, 1s. 4d. per yard run; 9 in. ditto, ditto, 2s. per yard run. The tanks and mixing-shed were tendered for at £127 ; 12 in. stoneware pipe outfall, jointed in Portland cement, at 1s. 9d. per foot run ; and 6 in. ditto, jointed in clay, at 1s. per foot run.

DISCUSSION.

The President, in inviting discussion, after pointing out the great importance of the subject of the drainage of small towns, said that it seemed to him that the 3 in. pipes referred to by Mr. Whitaker as having been used at Uppingham were very small indeed for a drain, for even in putting up a vertical soil-pipe in a dwelling-house no one ever thought of using less than a 4 in. pipe. It seemed to him that to lay down a 3 in. horizontal drain was "tempting Providence."

Mr. B. Haughton could have wished that Mr. Whitaker had touched at greater length upon the vexed question of sewage irrigation. At the present time there was an Act of Parliament which made it punishable for any one of the towns lying within reach of the Thames water-shed to throw their sewage into that river. But at present what were they to do? There were some half-a-dozen systems for getting rid of sewage before the public, but he was quite satisfied that no one of these was thoroughly sufficient for its object. It was not at all clear that sewage irrigation would do all that was claimed for it. At Barking there was a fine farm of about 300 acres, where the sewage of London had been experimented with for some years ; but if sewage irrigation was such a great success as it was said to be, why had not the farm been enlarged from hundreds to thousands of acres in extent? One of the greatest objections to sewage irrigation was that the quantity of sewage to be delivered upon the land was constant, whereas in some months of the year vegetation would absorb a much larger quantity than at other times. The sewage was obliged to be put out on the land whether it was required or not, and the consequence was, that the soil at times became saturated with fœculent matter. Some engineers said that this difficulty did not exist, or that if it did it could be overcome, but he was not at all satisfied as to this. It was quite clear that we had not yet arrived at a thorough solution of the sewage question. There was a very wide field open to engineers for invention, and whoever succeeded in thoroughly solving the question, might anticipate an ample reward. Birmingham, with its 450,000 inhabitants, after having gone to great expense in arranging for the disposal of its sewage by irrigation, was summarily stopped by the action of Sir Robert Peel and Sir Charles Adderley, and at present really did not know what to do. He believed that at Birmingham they had now constructed three or four subsiding tanks, getting rid of the solid matter as best they could. In one of the eastern towns (Lincoln, if he remembered rightly) they had tried the system of filtration, and had succeeded in producing an immense quantity of black fœculent matter, which they could not get anyone to take away on account of its worthlessness as manure.

Mr. W. Meakin thought it questionable whether sewage could be poured upon land in frosty weather (after passing through, in some cases, a long extent of sewer) with sufficient internal warmth to enable it to be taken up by the soil before freezing. Once the sewage was absorbed by the land, however, there was no doubt that its fertilizing properties would be stored up until the spring, when most required. There was, however, hardly any room for doubt, where the physical conditions were favorable, that in irrigation was to be found the real solution of the sewage question, rather than in the elaborate systems which had been experimented upon in some places. Mr. Haughton had rather understated the difficulty in which Birmingham found itself. It had not only been prevented from going on with the work of irrigation, but it had also been forbidden, by an injunction in Chancery, to continue to pour its sewage into the watercourses into which the sewage now went. It had, of course, been found impossible to enforce the order of the Court of Chancery. He agreed with the President in thinking 3 in. horizontal drain-pipes too small. It was surprising that the rude and primitive way in which drain-pipes were laid was allowed to continue in use in the present day. The method of making the joints, when well carried out, was, of course, perfectly sound, provided that the joints were never disturbed; but this could not be insured in all cases.

Mr. G. W. Usill could not agree with Mr. Haughton in saying that the sewage question had not been solved. True, it had not been solved so far as every town was concerned; but there was but one proper method of disposing of sewage, viz., by turning it upon the land. All towns might not be so situated as to make it easy to dispose of its sewage in that way, but in all but exceptional instances irrigation was the only possible system, and, with the exception of General Scott's method, no other system whatever had shown any symptoms of success. If the evidence of our first professors of chemistry was to be believed, there was no chemical means at the present day which would solve the question. Several of the processes would allow of the sewage water being rendered as clear as crystal, notwithstanding that it would still contain the germs of disease. It seemed part of the economy of nature that the sewage should go to the land, for that which was the bane of the human system was the food of the plant. Of course, in some places where there were physical difficulties in the way of irrigation, some one or other of the precipitation processes might be desirable. After tracing the history of the A B C process, which he characterized as a notorious failure and worse, the speaker said that one of the most successful of the precipitation processes was the milk of lime process. Having referred to the alacrity with which local boards and vestries seized upon the slightest pretexts for shelving the sewage question, Mr. Usill strongly denounced the way in which the Richmond sewerage competition had been conducted, and concluded by pointing out the sheer waste involved in pouring into our rivers thousands of tons of valuable matter, for which the land was absolutely crying out, and all this waste was incurred because local boards would not incur necessary expenditure for utilization works. It was a matter of primary importance that the sewage should be disposed of, whether at a commercial profit or not.

Mr. W. F. Butler was also unable to agree to Mr. Haughton's remark, that the sewage question had not been settled. The Rivers Pollution Commission had reported that irrigation was the only successful means known for the purification of sewage. Dr. Frankland had said that there was no chemical means at present known by which the sewage of towns could be purified. General Scott did not profess to purify the sewage; his process was put forward merely as a means of utilizing waste matter. The speaker then touched upon the importance of flushing drains and sewers, especially where the fall was not great, and described an invention which he had that day seen, of Mr. Rogers Fields', which he considered admirably adapted for the purpose. It consisted of a tank or barrel, made of cast-iron or stoneware, and holding 25 gallons and upwards. On the top of this tank was a cast-iron grating, under which was a trap for preventing the return of offensive smells. The house-slops, or other waste waters, were passed into the tank through the grating and trap, and when the tank was full, a siphon at the end, communicating with the drain, was called into action, and discharged the whole of the contents of the tank into the sewer. The invention was entirely self-acting, and required no attention whatever. Though intended for house purposes, the speaker considered it specially suited, on a larger scale, for flushing sewers. The cost of the apparatus varied from £2 to £5. Reverting to the subject of sewage irrigation, he wished to remark, on the authority of the Rivers Pollution Commission, that it was a chemical as well as a mechanical process. The ground had the property of storing up within itself and containing for almost any length of time the poisonous particles of sewage matter. Providing the soil was duly aerated, the oxygen of the air converted the ammoniacal matters contained in the sewage into substances perfectly harmless, and the process went on whether there was vegetation on the ground or not. This had been abundantly shown by passing sewage through a sufficient layer of gravel, quite irrespective of vegetation. In conclusion, Mr. Butler pointed out that the death-rate of Birmingham was from 4 to 6 per thousand higher than that of any other large town, and he thought that it was lamentable that a town of 450,000 inhabitants should have disease and death forced upon it by Parliament, merely because of the sentimental grievances of two members of Parliament, who happened to be large landowners in the locality.

Mr. E. Perrett observed, that in carrying out such works as the drainage of small towns, two sorts of engineering were required—the engineering of matter and the "engineering" of men. The latter was more often the most difficult of the two. Most of the successful engineers of the day knew how to "engineer" men better, perhaps, than they knew how to engineer matter. As Mr. Whitaker's partner and coadjutor in carrying out the works at Uppingham, he might say that the contract was absolutely executed for less money than the engineers had stated it would cost.

He thought that Mr. Butler had shown that the supposed difficulty of irrigating with sewage in winter did not exist. When the ground was laid out, as at Uppingham, any portion, or almost any portion of it, was capable of being used as an intermittent filter, and the reservation of a small portion of the land on a large sewage farm would entirely obviate the difficulty referred to. Lime had been justly described as one of the best precipitants, but it had the great disadvantage of destroying what little fertilizing properties the solid part of the sewage possessed. Although the A B C process had been exorbitantly overrated, it was, he believed, the best of the precipitating processes. It was constantly said, that by all means sewage must be utilized; but he would ask, if it cost more to utilize it than to destroy it, why utilize it? If it cost £10,000 a year to irrigate with sewage—and £10,000 spent in guano would do far more good for the farmer—why should the sewage be utilized? The 3 in. pipes referred to, were not for the sewage; they were simply pipes for draining away the effluent water.

Mr. Brewster asked what had been the effect upon the residents on or near to an irrigation farm using the sewage from a town which had been visited with an epidemic?

Mr. Whitaker, in replying, said he thought the success of sewage-irrigation had been demonstrated beyond a doubt. As to the small pipes to which the President had referred, perhaps no one would have the temerity to lay a 3 in. drain-pipe as a sewer; but if the inclination were sufficiently good, and the joints well made, he saw no reason why it should not take the sewage of one house or of a small court, as well as a 6 in. pipe. It should be remembered that the solid excrementitious matter became broken up and disintegrated on leaving the soil-pans, and the chance of its choking up the pipes was very remote indeed. Irrigation was not, perhaps, the panacea for getting rid of sewage in every case; but where it was not possible, intermittent filtration might be resorted to with advantage. All soils, according to Dr. Frankland, were equally well suited for the purification of sewage, although with some the operation was quicker than with others.

At Conventry it had been found that no inconvenience whatever resulted on the sewage-farm during the prevalence of frost. Probably at Harrow there was only a small stream trickling from the outfall, not sufficient in volume to resist the frost. In conclusion, Mr. Whitaker said that while he would not attempt to lay down drain-pipes theoretically correct, he thought it was desirable to endeavor to approximate more nearly to accuracy than was the case at present; rule of thumb was more in the ascendant than it should be. In answer to Mr. Brewster's question, Mr. Whitaker said he had never heard of any injurious effect resulting to the residents of a farm irrigated with sewage from a town visited with epidemic disease.

THE SUCCESSFUL UTILIZATION OF BLAST FURNACE SLAG.

From "The Mining Journal."

Among the many efforts made at the utilization of waste vitreous products, none have been more successful than those that have just assumed a practical and definite shape on Tees Side. The blast furnaces of the North of England now produce about 2,000,000 tons of pig-iron per annum. For every ton of pig-iron made there is 1½ ton of slag, so that at the present time the waste vitreous products of northern metallurgy must be accumulating at the rate of about 3,000,000 tons per annum. It is calculated that about 25,000,000 tons of slag have been produced in the North of England since Messrs. Bolckow & Vaughan first commenced to smelt the iron ore of Cleveland, in 1851. This immense volume of material necessarily covers many acres of ground, which could otherwise be rendered available for industrial or agricultural purposes. Every establishment where smelting operations are carried on must have its slag-tip. It is as necessary as the blast-furnace itself; and it often happens that this slag-tip takes possession of ground that can ill be spared. Some of the principal works in the Middlesborough district, such as those of Bolckow, Vaughan & Company, Hopkins, Gilkes & Company, and Stevenson, Jacques & Company, have recently gone to the cost and labor of removing their slag to a considerable distance, rather than allow it to occupy land which is necessary for building or other purposes, and for which they can realize a high value. Such cases are, however, exceptional. As a general rule, a high slag heap will be found adjacent to all smelting establishments, and where the area of such works is of limited extent, the proprietors are always perplexed with the question of how the slag is to be got rid of when the land available for its deposit is entirely filled up. It is, probably, not too much to assume that each of the forty different firms connected with the Cleveland district, has on an average 10 acres of land appropriated for the deposit of slag; and if ways and means of profitably and successfully utilizing these waste vitreous products could be discovered, these 400 acres would be useful and productive, whereas they are now useless and unproductive. But this is not all, nor even the worst of the matter. The removal of the slag from the blast-furnace to the "tip" involves the employment of a regular staff of men, who are as permanently attached to all smelting establishments as chargers or keepers. These men are paid a high rate of wages, and their employment is a regular and unavoidable tax upon the ironmaster. In the North of England this tax is more severely felt than elsewhere, because on account of the poorness of the ores of Cleveland, which do not contain more than 28 to 34 per cent. of iron, the educt of slag is much more considerable than it would be in districts or at works where the ores used contained from 40 to 60 per cent. of metal. To the North of England, therefore, this question possesses an amount of interest and importance such as it cannot have in any less extensive centre of metallurgical operations. Attention has again and again been called to the practicability of utilizing this scoriæ, and plans without number have been proposed and acted upon with that end in view. But none of these plans had the elements of permanence about them, nor were any of them so comprehensive as to include one-half the works in the district. The most, indeed, that has ever been attempted in this direction has been the construction of the Tees Breakwater by the Tees Conservancy Commissioners, who will have used over 3,000,000 tons of slag in this great undertaking when it is completed. The problem of the permanent and complete utilization of scoriæ remains, or did until lately remain, apparently as insoluble as ever. We are glad, however, to be able to say that there is now every likelihood of this prolific source of waste and difficulty being removed. Competition, as our copy-books used to tell us, is the soul of business, and the fact of competing plans for the utilization of clay having been projected, will stimulate the efforts of those who are endeavoring to effect the accomplishment of this desirable end.

Along with some of the Directors of the Tees Scoriæ Brick Company we had an opportunity a few days ago of witnessing the operation of Mr. Woodward's patent plan for the manufacture of bricks from slag. It was at the Clay Lane Works of Messrs. Thomas Vaughan & Company where the manufacture was shown. Here there are some kilns erected, with other necessary appliances for the process, which commences with the removal of the slag in bogies, or otherwise, to the vicinity of the ovens. The slag is here allowed to run into moulds, which are filled as rapidly as they can be removed, while the slag is yet in a hot state, to the moulding oven or flue. After they have remained here for a certain period, not exceeding 30 hours, the bricks are found to have a fine hard skin, and are otherwise equal to any ordinary paving or fire-bricks. There are features of Mr. Woodward's process susceptible of improvement; and where there are defects in respect of mechanical details they will, doubtless, be remedied in course of time. But all this has hitherto been subordinate to the great question—is it possible to make from scoriæ, bricks that can compete with ordinary bricks as regards quality, and at the same time prove economically and commercially successful? This question Mr. Woodward has practically answered in the affirmative. For paving and channelling purposes, nothing could beat the bricks we saw produced by his process. They were quite equal to such bricks as are now sold in the market at £3 to £4 per 1,000, and they can be made to sell at a profit for 50s. Indeed, a lot of them has been sold at the latter figure to a Stockton firm, which has expressed the utmost satisfaction with the purchase.

The specific gravity of Cleveland slag varies from 2.9 or 2.10 to 2.6, or even less in varieties that are full of minute vesicles. The mean specific gravity of all the different slags taken together has been set down at about 2.8, so that the mean weight of a cubic foot is 192 lbs. or 11.6 cubic ft. per ton, being thus of about the same density for building purposes as basalt or granite. Hence the greatest speculative objection urged against the employment of slag for building purposes arises from its weight; and it would be useless to deny that this is to a large extent a rational and fair objection.

Slag bricks cannot be made so light as ordinary red or fire-bricks, unless they were exposed to chemical treatment, which is calculated to impair their efficiency and increase their cost. But seeing that a high quality and cheapness of production are combined in the scoriæ bricks, these advantages ought to offer full compensation for the difference of weight. We had the opportunity of seeing the relative weight of slag bricks and clay compared at the Clay Lane Works, and the result showed that on an average the former exceeded the latter by about 2 lbs. Thus, an ordinary firebrick weighs about 9 lbs., while a slag brick suitable for the same purposes will weigh about 11 lbs. The weight of a red brick is about 7 lbs., while a slag brick suitable for ordinary purposes is about 9 lbs. With this single exception the slag brick is in all respects equal, if not superior, to the other. It will bear a much greater strain, for we ourselves tested its hardness to this extent; and it is allowed to be quite as durable. Nothing, therefore, seems wanting but energy and enterprise to take up this new industry, and carry it on to such an extent as will render it commercially successful.

It would be unfair to withhold allusion to the efforts that are now being made by the Tees Slag Company to attain the utilization of that product. This company has purchased the patent right of Mr. Wood and Capt. Bodmer, and are about to erect works near to the Tees Ironworks for the manufacture of building materials on a large scale. It remains to be seen which of the two processes will be the most successful from a commercial point of view; but both have demonstrated the practicability of the end aimed at. At the next meeting of the Cleveland Institute of Engineers Mr. Wood will read a paper on his process, and from that and the discussion thereupon we are likely to glean some statistical data. It is the eve of a revolution in the metallurgical industry of Cleveland, for if the two companies now aiming at the utilization of slag accomplish all their intentions, they will not only induce others to enter the field, but they will succeed in making slags, now worth less than nothing, a commodity of value to the ironmaster, and so cheapen very materially the cost of his manufacture.

ON THE APPLICATION OF SOLAR HEAT AS A MOTOR FORCE.

(G. A. BERGH in "Poggendorff's Annalen.")

From "The English Mechanic and World of Science."

That the heat of the sun may be transformed into mechanical force no one can doubt; for we see daily what masses of water solar heat raises into the air, to be again precipitated to the earth, and we know what an enormous mechanical force is here represented. Further, we know that solar heat is the cause of motions of the atmosphere, that plants under its influence form out of the carbonic acid of the air, an organic substance richer in carbon; that plants which grew in earlier times, under the influence of sun heat, were transformed into coal and peat, whose combustion now yields heat to drive our engines, which is simply the solar heat returned.

But while solar heat is the cause of nearly all mechanical force developed on the earth, we have yet hitherto known of no means whereby it may be directly utilized for mechanical work. It has been proposed, indeed, to employ solar heat, concentrated by lenses or mirrors, for driving a steam or caloric machine. These machines, however, are not suited for this, as they involve too great a waste of heat. Moreover, in concentration a large quantity of heat must be lost. These circumstances, as also the fact, that the concentrating apparatus must always be moved according to the motion of the sun, have rendered such machines impracticable.

Sun machines must be so arranged, that the solar heat absorbed by a given surface may, without too great waste of heat, be directly transformed into mechanical work.

We propose to inquire how such a machine may be had.

It is known that the arrangement of machines, which serve for the tranformation of heat into mechanical work, rests on the principle that a liquid or gaseous substance, acted on by the heat, undergoes a molecular change, through which a certain mechanical force is developed. The changes of solid bodies, under influence of heat, are too small for transformation of the heat into mechanical work, or to render them means of movement, although through such molecular change a certain mechanical force is developed. Gaseous bodies have been applied as means of movement in the caloric and gas machines; but, with the small differences of temperature which occur in some machines, they cannot be employed as such, with advantage. Thus nothing remains but to employ a liquid; and it must be one whose boiling-point is very low. We know that the great expenditure of heat in steam-engines is due, in great part, to the high boiling-point of water. The higher steam-pressure we have in the boiler, the greater is the quantity of heat transformed into mechanical work. Hence, if we had a liquid which, at ordinary temperature, behaved like water at a high temperature, this liquid would be a suitable means of motion for a sun machine. There are several such liquids, *e. g.*, sulphurous acid, methylic, chloride, methylic ether, etc. Of all these, sulphurous acid best deserves attention, as it has several useful properties for the end in view. It is not too difficult to condense, and it can be got at a moderate price. The keeping of it presents no difficulties, and it may quite well be put in ordinary steam-boilers. Now, we have got the principle on which we must construct our sun-machine. Conceive a vessel, filled with sulphurous acid, exposed to the sun's rays; the tension of the sulphurous acid vapor, if the temperature of this vessel exceeds that of the surrounding air by at least 10 deg. to 20 deg., must be from 1 to 3 atmospheres higher than that of the sulphurous acid vapor in another vessel B, similarly filled with sulphurous acid, but which has only the temperature of the surrounding air. We can thus arrange an engine which agrees in principle with the steam-engine with merely this difference, that the water is replaced by sulphurous acid, and the fuel by the solar heat; while the vessel exposed to the sun's rays represents the steam-boiler, the vessel kept at ordinary temperature may represent the condenser. The sulphurous acid condensed, after doing work in vessel B, could easily be driven back by a force-pump into the boiler representing vessel A. The capability of work of such a machine must naturally increase with the amount of heat communicated to vessel A, or be proportional to the surface exposed to the solar rays.

If, now, we conceive, a factory or shop, the roof of which is covered with vessels containing sulphuric acid, and which is furnished with a sun-machine, made on the above principle, such a machine might, indeed, work while there was sunshine; but in default of this, the establishment would be brought to a standstill. True, the solar heat might be replaced by the heat of the air, if the temperature of the air were pretty high, and one had at hand a cooling substance like ice. But as this is not always the case, the establishment should have, besides the sun-machine, an apparatus which might "store up" some of the work done by this. As such, Natterer's apparatus for condensing carbonic acid, might, with great advantage, be used. If a supply of carbonic acid were kept in a large gasometer, like those in ordinary gasworks, the Natterer apparatus might be fed from this. In a wrought-iron vessel thus filled with liquid carbonic acid, we should thus have an enormous store of mechanical force, which might be made to replace the action of solar heat in the sun-machine, partially or wholly. After work done, the carbonic acid, become gaseous again, might be collected in the gasometer. Or, again, the sun-machine, while in action, might drive an ice-machine, and might, in default of sunshine, profit by the ice it had produced, for maintenance of its working.

We thus see that from the present standpoint of science, it is possible to construct a constantly working sun-machine.

SERVIAN RAILWAYS.—The principal conditions proposed for the construction of a railway in Servia are as follows: The concession is to be granted for a term of 50 years, but the Government is to have the option of purchasing the line at the expiration of 20 years. The undertaking is to be called "The Servian State Railway," and it is to have a double line of rails.

ON A METHOD OF REFINING AND CONVERTING CAST IRON INTO IRON OR INTO STEEL.*

By Sir FRANCIS CHARLES KNOWLES, Bart., F. R. S.

From the "Journal of the Society of Arts."

The object of this method, generally stated, is the refining or purification of cast iron from sulphur and phosphorus, and its conversion into iron, or into steel, of various qualities, according to the nature of the metal treated, with an increased yield of malleable iron or steel per ton of metal.

The ordinary puddling furnace is at one and the same time time a generator of gases and a converting vessel, of simple construction requiring no motive power, and readily admitting of the application of manual labor to conduct the process which it is intended to perform. But, on examining more closely its operations, we shall perceive that the above advantages are more apparent than real. The gases generated depend for their production on their own combustion, and the greater part of the heat which they evolve goes to heat the chimney stack, and to create the necessary draught, after which it is wasted. That part of it which is applied to the metal is applied under a great disadvantage, and by the aid of the most severe form of manual labor; and the chemical action of the heated air, in its oxidizing of the impurities and of the carbon of the metal, is discontinuous and uncertain, and involves, besides, the needless oxidation of much of the metal itself. Both the heating flame and the re-agents, where used, are applied on the surface of the bath, which is protected by a layer of liquid scoriæ of great specific heat, except when the rabble exposes the metal, while the re-agents are diluted or decomposed by the scoriæ. These disadvantages become more sensible in proportion to the degree in which other re-agents than heated air are to be applied to the purification of the metal. The present is an attempt to devise a method which should be free from the waste of heat and material which takes place not only in puddling, but also in methods of more recent origin.

The means adopted are:—

1. The separation, as far as possible, of the heating process from the chemical process.

2. The securing of a highly basic scoria—or cinder—of not exceeding 30 per cent. of silica, by means of finery and converting furnaces in which that acid is not present.

3. The employment of caustic soda in conjunction with pure and rich oxide of iron in the elimination of the sulphur and of the phosphorus.

4. Where pure cast iron is treated, and superior iron or steel is to be produced, the use of nitrate of soda, or of permanganate of soda.

The source of heat employed is the complete combustion of gases rich in carbonic oxide gas combined with heated air to 500 deg. C., in due proportion. The metal being first melted in a cupola with pure dense coke or anthracite coal, the resulting gases are collected and utilized by freeing them from carbonic acid (if any), and enriching them with pure carbonic oxide gas, cheaply produced, until a compound is obtained of from 70 to 80 per cent. of carbonic oxide gas and 30 to 20 per cent. of nitrogen; or, if a higher heat be required, a larger charge be treated, and a more speedy operation be the object, the cupola gases are used to heat the retorts, and pure oxide of carbon, as described below, is generated for the purpose.

In the former case a temperature of combustion of 2,500 deg. C. and upwards is obtained, in the latter one of 2,979 deg. C., without taking into account the heat (500 deg. C.) of the air and gas, and the pressure, as it is easy to calculate from the data of the case.

The gas (in either case) being mixed in the condenser with hot air in the proportion to insure the production of only carbonic acid gas and nitrogen by the combustion, with no excess of air, is blown into the body of the metal bath by appropriate apertures at the level of the hearth or sole, giving, therefore, a neutral flame, while the carbonic acid gas and the nitrogen rising from below with force in all directions, and, aided by the natural lightness of the hotter metal, stir, agitate, and mix the particles of the metal, and so bring them all successively

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* A paper read before the Society of Arts.

into contact with the re-agents employed, and with each other, doing in fact the work of the puddler. The iron can be "balled" by simple machinery. The blast is urged, in the Bessemer plant, by an engine of from 250 to 300 horse power, adapted to appropriate sucking and forcing pumps, and the gaseous mixture enters the bath at a pressure of about 1.2 atmospheres. From this it appears that in practice there is an injection of about 1 cubic metre, or of something less than 35.5 ft. per second

The gases are collected in gasometers, the hot air in the usual apparatus. The stopcocks in the leading pipes are so regulated by a graduated scale as to allow the proper volumes to pass under the given pressure into the condenser.

The carbonic oxide being thus burned with a neutral flame, the carbonic acid gas that is formed and the nitrogen quit the surface of the bath at an intense heat (2,150 deg. C., subject to radiation and conduction), which heat may be easily utilized. If the gaseous product of the combustion be passed through a kiln or retort of anthracite coal or of coke, the carbonic acid will take up a second equivalent of carbon, and one volume of it will yield two volumes of carbonic oxide, which absorb 2,400 units of heat per kilo. of weight, the nitrogen remaining constant. A computation given below will show that the resulting gas contains about 47 per cent. of carbonic oxide. If, after a second combustion this conversion of $C\ O_2$ into $C\ O$ be repeated, the proportion of $C\ O$ to N will fall to 39.71 per cent., and so on in a decreasing ratio, until we arrive at 34 per cent., the ratio of the cupola gas. The carbonic acid may thus be used as an economical beast of burden to carry fuel to its destination. These converted gases may be used first to heat the generating retorts, and may finally pass into the flues of the boilers, which, with good management, ought to be heated without any other fuel. (If desirable, the nitrogen may be freed from the remaining carbonic acid gas and obtained pure, in which state it may possibly be turned to good account in the preparation of cyanides.)

Enough has been said to show, as the degree of heat generated is indisputable, that the sufficiency of the finery or converter to resist the intense heat evolved and the corrosion by the reagents, is the main condition of the success of this process in the physical and chemical point of view. The question of its commercial success will be considered subsequently.

In order to insure this condition, the finery or converter is made of pieces of cast metal, so constructed that the tuyeres may form one piece with the casting itself. In fact, they are bored out of the solid casting itself, and the apertures are countersunk to meet them at the level of the hearth. The whole is bound together by an exterior jacket of well-riveted boiler-plate, so that in case of an accidental fracture of the castings there may be no danger of the access of water to the molten iron. The whole finery (or converter) is enclosed, and well supported in an iron tank or cistern, through which run currents of cold water adequate to prevent fusion of the sole or walls of the finery. In order to protect from corrosion the interior of the finery, which the re-action might cause, a basic paste is formed of protoxide of iron, or as nearly such as may be, or of manganese, of Naxos emery or bauxite (an aluminous mineral used in France for making aluminium), and caustic soda in small quantity. This is laid on in thin layers, which, when gently dried, are successively reduced to a state of pasty fusion by the flames of the gases, so that the particles of the mixture may cohere, and furnish a lining of adequate thickness in the form of a semi-enamel or glazing. The best Naxos emery is now quoted at £12 per ton in the stone. This lining is so slowly fusible if the soda be not in excess (which economy alone will prevent) that it will last a long time, and cause but a trifling cost per ton of metal. So far as it is fused, being highly basic, it will be an advantage to the scoria, and it is a bad conductor of heat. Its basic nature is of great importance. It will be seen on reference to Baron Gruner's last pamphlet, "Etudes sur l'Acier et le Procédé Heaton" (Dunol, Paris), that he considered it as a *sine qua non* for the elimination of the phosphorus that the maximum dose of silica in the scoria should be 30 per cent.; and he cites, in confirmation of his opinion, Berthier's analysis of the only cinders which were found to contain phosphoric acid. The fulfilment of this condition would enable us to make at once good bar iron or steel from the oolitic iron ores of Cleveland, Northamptonshire, Lincolnshire, Belgium, and the North of France.

There remains only one more point to be considered, namely, the efficiency of the re-agents, caustic soda, and the rich oxides of iron or manganese. As the former substance is costly, it must be used with due precaution against waste. Accordingly, where the metal treated contains much silicium, or where sand adheres to it from the casting-bed, it must undergo a preparatory refining with peroxide of iron alone, if possible, with the variety of red hematites (to be found in abundance in Devon and Cornwall), containing only carbonate of lime as its gangue. The silica, and much of the sulphur and phosphorus, being thus expelled, and the scoria being removed, the metal is to be treated with caustic soda and peroxides of iron free from silica. Manganesiferous spathose ore calcined, or calcined spathose ore, with the addition of from 5 to 10 per cent. of oxide of manganese, pure and rich magnetic ores, particularly iserine, which contains about 10 per cent. of titanic oxide, are the most valuable adjuncts.

It is hardly necessary to argue in a chemical point of view the superiority of these re-agents; if, indeed, there is room for comparison between the use of a pure detersive re-agent, and that of scoriæ already charged with the very substance which is to be expelled. But we need not resort to chemical affinities to establish this efficiency. Both nitrate of soda and caustic soda with oxides of iron have been tried in the common puddling furnace, and in the Heaton converter, and the scoriæ produced in the latter case, when tested by the analysis of the late Professor Miller, F. R. S., and subsequently by those of Baron Gruner, were found to contain phosphate of soda, while the metal had lost above 80 per cent. of its phosphorus, under the oxidation of the nitrate, and in presence of the alkaline base, which it is evident, as in other analogous cases in chemistry, had induced the combination of the phosphorus with the oxygen present in a nascent state. More than this, sodium was found in the metal, which both Professor Miller and Baron Gruner affirm forms volatile compounds with the residue of the phosphorus, and thus leads to a further cleansing of the metal in the ulterior stages of manufacture. The quality, moreover, of the iron produced by the author in his works at Flint with nitrate of soda, after treatment of the iron with peroxide of iron, aluminous kaolin, and lime, was extraordinary; for the metal treated was no better than a charge of three-fourths of the cheapest and most ordinary scrap metal with one-fourth of grey metal, made from a brown hydrated peroxide of iron (a decomposed spathose ore). Rivet rods made with it were tried in the factory of Portsmouth Dockyard, and were pronounced to be at least equal to best Lowmoor or Bowling rivet iron. The author has samples, both of this and of iron made with oolitic ores without admixture, which speak for themselves.

The converter destined for casting steel, or homogeneous iron, is cast in one or two pieces, and has a similar jacket of boiler plate with a similar lining, or enamel. I is movable, so as to admit of being hoisted by a chain and pulley, and removed by a crane for casting or charging. The tuyeres are bored in flanges at the side, and communicate with an aperture at the bottom of the hemispherical, or hemiovoidal vessel. The whole, as in the case of the finery, is placed and firmly supported in a cistern or tank of running water. The casting may be conveniently made through the tuyeres themselves, and the steel is to be poured into moulds, just as in the method of Mr. Bessemer. The saving of wear, as compared with the wear of any finery or converter at present in use, must be very large, the wear in fact being confined to the enamel lining, which will in each heat become at once slightly viscous on the surface.

Such is the outline of this very simple process, and the author leaves it for consideration whether more heat is required to produce the mechanical power employed in it than now goes up the chimney of the puddling furnace, or would be required for any conceivable system of mechanical puddling.

It remains to exhibit the calculations which measure the quantities of the gases employed, their temperatures of combustion, and their effective heating powers; and their cost of production with the cost per ton of iron of this method of treatment.

1. To calculate the composition of the cupola gases, we may take 2½ cwt. per ton of cast metal as about the weight of coke or anthracite coal required to melt that ton. Let W^1 be the weight of carbon contained in this (which will vary from 91 to 98 per cent. in the anthracite coal). Then the oxygen required to form with this carbon carbonic oxide gas will be

$$\frac{8\,W^1}{6} = \frac{4\,W^1}{3};$$

and $\frac{77}{23} \times \frac{4\,W^1}{3}$

will be the weight of the nitrogen in the air which the blast supplies for it. Therefore, the compound gas of the cupola per ton of molten metal will be represented by

$$\left(W^1 + \frac{4\,W^1}{3}\right) + \frac{4}{3} \times \frac{77}{23} \times W^1$$

and the richness of this gas in carbonic oxide will be measured by the fraction

$$\frac{\cdot\,\frac{7\,W^1}{3}}{\frac{7W^1}{3} + \frac{4}{3}\,\frac{77}{32} \times W^1} = \frac{7\,W^1}{7\,W^1 + 4 \times \frac{77\,W^1}{23}} = \frac{1}{1 \times \frac{44}{23}}$$

$$= \frac{23}{67} \text{ or } 34.32 \text{ per cent.*}$$

2. This cupola gas being given, and also a supply of pure carbonic oxide, in what proportion by weight must they be mixed in order to produce a gas consisting of 75 per cent. of carbonic oxide and 25 per cent. of nitrogen?

Let the weight per ton of molten iron of the cupola gas be called.

$$C = \frac{7\,W}{3} + \frac{4}{3} \times \frac{77\,W^1}{23},$$

and let x be the weight of carbonic oxide gas required.

Then, by the conditions of the question, we must have:—

$$\frac{34.32}{100}\,C + \frac{100}{100}\,x = \frac{75}{100}\,(C + x),$$

from which equation we deduce,

$$x = 1.627\ C, \text{ and } x + C = 2.627\ C.$$

we readily find—

$$\frac{7\,W^1}{3} = \frac{\text{cwt.}}{7.6766} \text{ and } \frac{4}{3} \times \frac{77\,W^1}{23} = \frac{\text{cwt.}}{14.6851},$$

whence we have value of

$$C = 22.3620 \text{ cwt., and } x + C = 58.745 \text{ cwt.}$$

Thus the carbonic oxide at our disposal will be .75 × 58.745, or nearly 2 tons 4 cwt., the only part which is not waste gas being x=36.383 cwt.

3. To determine the temperature of combustion of this gas, its initial heat and that of the air being 500 deg., our data are as follows:—One kilo. of carbonic oxide in burning evolves 2,400 units of heat, or calories, and the products of combustion are carbonic acid and nitrogen. The specific heat of carbonic acid is .216, that of nitrogen is .244. Of the proposed gas, $\frac{3}{4}$ kilo. are carbonic oxide, and $\frac{3}{4}$ kilo. nitrogen. It will come to nearly the same thing whether we consider the carbonic oxide and the oxygen and nitrogen to be heated to 500 deg., or the carbonic acid and the nitrogen be so heated. We have upon this data:—

$\frac{3}{4}$ kilo. × 2,400, giving out 1,800 calories.

To burn $\frac{3}{4}$ kilo. of carbonic oxide, we require $\frac{8}{14} \times \frac{3}{4}$ kilo. of oxygen, making $\frac{33}{28}$ kilo. of carbonic acid, and importing $\frac{77}{23} \times \frac{3}{7} = \frac{33}{23}$ kilos. of nitrogen from the air;

Thus the total nitrogen will be $(\frac{1}{4} \times \frac{33}{23})$ kilos. or $\frac{155}{92}$ kilos.

The specific heats for 1° are:—

Of the carbonic acid gas $\frac{33}{23} \times .216 = .2546.$
" " nitrogen $\frac{155}{92} \times .244 = .4110.$
Sum...................... = .6656.

Therefore for ($t°$ — 500°) the number of degrees to which the products are raised, this sum will be—

$$.6656 \times (t^0 - 500^0)$$

which is to be equal to the sum of the calories developed, that is—

$$.6656\,(t^0 - 500^0) = 1800,$$

and for the temperature of combustion $t°$,

$$t = \frac{1800 + 500 \times 6656}{6656} = \frac{1803.328}{.6656} = 2709° \text{ C.}$$

(This does not take into account the effect of the compression.) Chevalier Bunsen made the temperature of combustion of pure carbonic oxide 3,042° C.; the above data give 2,979° C. The gas resulting from the first conversion of $C\,O_2$ in the above products into C O, viz., 47.09 per cent. of carbonic oxide gives a temperature of 2,221° C., independently of its initial temperature.

The cupola gas gives 1,900° C. nearly, which, it is evident, is more than is required to heat the retorts or the air.

4. The carbonic oxide being 75 per cent., and the nitrogen 25 per cent., if we put the former $= W^1$, we have the latter $= \frac{W_1}{3}$, and the composition of the gas will be denoted by $W_1, + \frac{W_1}{3}$. The oxygen required to burn this gas completely is

$$\frac{8\,W^1}{14} \text{ or } \frac{4\,W_1}{7},$$

---

* This agrees within a few hundredths with the result of direct analysis of generator gases.

1*st Combustion*—The CO_2 yielded is :—

$$W_1 + \frac{4\,W_1}{7} = \frac{11\,W_1}{7}$$

The nitrogen due to—

$$\frac{4\,W_1}{7} \text{ is } \frac{77}{23} \times \frac{4\,W_1}{7} = \frac{44\,W_1}{23} \times 7.$$

and the total nitrogen is

$$\frac{W_1}{3} + \frac{44\,W_1}{23}$$

1*st Conversion.*—By passage through the kiln of anthracite or coke.*

To form $C\,O$ from $C\,O_2 = \frac{11\,W_1}{7}$ we must add to it of carbon $\frac{6}{22} = \frac{11}{7} \times W_1$; thus giving of $C\,O$ the weight

$$\frac{11\,W_1}{7}\left\{1 + \frac{6}{22}\right\} = \frac{11}{7}\left\{\frac{28}{22}\right\} = 2\,W_1.$$

The composition of the gas will now be,

$$2\,W_1 + \frac{W_1}{3} + \frac{44\,W_1}{23}$$

and its richness in $C\,O$ will be measured by the fraction—

$$\frac{2\,W_1}{2\,W_1 + \frac{W_1}{3} + \frac{44\,W_1}{23}} = \frac{1}{1 + \frac{1}{6} + \frac{22}{23}} = \frac{47\;09}{100}$$

2*d Combustion.*—To burn this gas completely, the O required is—

$\frac{8}{14} \times 2\,W_1$, and the $C\,O_2$ produced is $2\,W_1 \left\{1 + \frac{8}{14}\right\} = 2\,W_1 \times \frac{11}{7}$.

The nitrogen corresponding to O in the air is—

$$\frac{77}{23} \times \frac{4}{7} \times 2\,W_1 = \frac{44}{23} \times 2\,W_1$$

and the total nitrogen becomes—

$$\frac{W_1}{3} + \frac{44}{23}\,W_1 + \frac{44}{23} \times 2\,W_1 = \frac{W_1}{3} + \frac{44}{23} \times 3W_1.$$

2*d Conversion.*—To convert this CO_2 into C O, we require of O,

$$\frac{6}{22} \times \frac{11}{7} \times 2\,W_1$$

and the C O formed will be now,

$$\frac{11}{7} \times 2W_1 \left\{1 + \frac{6}{22}\right\} = \frac{7}{11} \times 2\,W_1 \times \frac{28}{22} = 4\,W_1$$

The composition of the gas will be as follows :—

$$4\,W_1 + \frac{W_1}{3} + \frac{3 \times 44\,W_1}{23}$$

Its richness in C O is measured by the fraction

$$\frac{4\,W_1}{4W_1 + \frac{W_1}{3} + 3 \times \frac{44\,W_1}{23}} = \frac{4\,W_1}{4 + \frac{1}{3} + 3 \times \frac{44}{23}} = \frac{39.71}{100}$$

The law of the progression is evident, as well as the economy of the process. These gases may be used in heating up the metal bath, but they may be better employed for the retorts and the boilers of the steam engines. We may readily compute their temperatures of combustion, but it must be remembered, in employing the data above given, that, unless we take into account the temperature 2,150 deg. C., at which it will be seen they rise from the bath, as well as the specific heat of the fuel employed to give the additional equivalent of carbon, we shall have our results much below the actual temperature of combustion.

It might seem that there is a loss of heat in the conversion of the $C\,O_2$ into $C\,O_1$, one volume yielding two; but this heat 2,400, units for each kilo. of the gas, is in reality stored up and is given out again upon its combustion. This is to be borne in mind when we come to the conversion of the carbonic acid gas of limestone into carbonic oxide.

5. The blast engine of from 250 to 300 horse power, delivering at a pressure of 1.2 atmospheres, 1 cubic metre, or 35.3198 cubic feet per second, required the weight of carbonic oxide gas injected into the metal bath, the gas containing it (viz. 75 per cent. C O and 25 per cent. N) being combined with the weight of air due to complete combustion.

Let W_1 be the weight of the gas required, then is $\frac{W_3}{3}$ the weight of the nitrogen combined with it. Let—

$$\left.\begin{array}{l} s_1 = \text{the specific gravity of } W_1 = .9.708 \\ s_2 \quad \text{“} \qquad \text{“} \qquad \text{“} \quad \frac{W_1}{3} = .9.760 \end{array}\right\{ \begin{array}{c}\text{the sp.} \\ \text{gr. of} \\ \text{air} \\ \text{being} \\ \text{1,000.}\end{array}$$

As 1 cubic foot of air weighs 1.2 oz. avoir., if we make 1.2 the unit, we must put $s_1 = .9{,}706 \times 1.2$, and $s_2 = .9{,}760 \times 1.2$. Let W be the weight of air due to complete combustion, W_2 that of the nitrogen of the mixed gas, then the total weight will be—

$$(W_1 + W_2 + W) \times 1.2 \text{ atmosphere.}$$

---

* The blocks of anthracite, or coke, being continually heated by the gas of combustion, have all the advantages of Mr. C. Siemens' regenerating furnace.

The total volume injected in one second will be the sum ef the volumes of the air and of the component gases, that is of each component in the blast, and will be equal to the sum of their weight divided by their specific gravities respectively, that is, we must have in one second of blast—

$$\frac{W_1}{s_1}+\frac{W_2}{s_2}+\frac{W}{2}=35.3,198 \text{ ft.}^3.$$

Now, $W_2=\frac{W_1}{3}$ (by hypothesis). The oxygen required to burn W_1 is $=\frac{8}{14}\times W_1 = \frac{4}{7}W_1$, and the nitrogen of the air which furnishes this oxygen will be $\frac{77}{23}$ of its weight, so that we have

$$W=\frac{4}{7}\left(1+\frac{77}{23}\right)W_1=\frac{4}{7}\times\frac{100}{23}\times W_1.$$

Thus finally we obtain

$$\frac{W_1}{s_1}+\frac{W_1}{3\,s_2}+\frac{4}{7}\times\frac{100}{23}\times\frac{W_1}{1}=35.3,198 \text{ ft.}^3$$

If we put 1.2 for the unit of air we get $s_1=.9,706\times 1.2$, and $s_2=.9,760\times 1.2$, so that the equation becomes—

$$\frac{W_1}{.9,706}+\frac{W_1}{3\times 9,760}+\frac{400\,W_1}{7\times 23}=35.3,198\times\overset{\text{oz. av.}}{1.2}\times\overset{\text{atmo.}}{1.2}.$$

Whence we obtain for the value of the weight W_1 sought—

$$W_1=\frac{31.3,198\times\overset{\text{oz. av.}}{1.2}\times\overset{\text{atmo.}}{1.2}}{\frac{1}{.9,706}+\frac{1}{3\times .9,760}+\frac{400}{7\times 23}}$$

Effecting the numerical calculations indicated, we find

$$\begin{aligned}W_1 &= .260\times 1.2\times 1.2\times 35.3,198 \text{ oz. av.}\\ &= .82,648,332 \text{ lbs. av. per second of time.}\end{aligned}$$

Thus the weight of carbonic oxide gas injected per hour is 2,975.333 lbs. In two hours (which for the present will be assumed as the utmost limit of the operation, in order to compare the results with those of ordinary puddling) the weight injected is 5,950 lbs., or nearly 2 tons 13 cwt. 0 qrs. 14 lbs.

If pure carbonic oxide be employed the quantity blown in and burned in the same time is not quite 4 tons. This may be calculated by neglecting the second term in the denominator of the fraction, which term represents the nitrogen in the compound gas.

It has been shown that we can command, by admixture of the pure carbonic oxide with the cupola gases, 2 tons 3 cwt. (if need be) per ton of iron of the above gas, so that there is an ample supply for all purposes. We are thus able to insure any temperature of combustion from 1,900 deg. C to 2,979 deg. C, which, besides refining and converting the cast iron, may enable us to form valuable alloys with other metals, which alloys have hitherto been thought to be hopeless on the scale of manufacture.

If we employ pure carbonic oxide, which it is probable, as we shall see presently, would be the most economical in time, labor, and fuel, and then convert successfully in the products of combustion the CO_2 into CO, as above described, we shall find as follows:

	C O per cent. in the gas.	Temperature of combustion. Deg.
1st conversion	51.11	2.355 C.
2d "	41.07	2,075
3d "	37.40	1,976

Pouillet found the point of fusion of "spiegeleisen" to be from 1,050 deg. to 1,100 deg. C., and we see that our lowest temperature much exceeds it. Grey metal, according to his assays, melted at from 1,100 deg. C. to 1,250 deg. C.

The following is a table drawn up up by M. Pouillet:

POINTS OF FUSION.

Of slightly fusible white cast iron.....	1,100 C.
Of slightly fusible grey cast iron......	1,300
Of slight fusible steel................	1,400
Of malleable iron....................	1,600

Plattner makes the point of fusion of malleable iron 2,100 deg. C., and the author has taken this as the greatest heat to which the metal bath need be raised, though he regards M. Pouillet's as the better determination. It is, however, quite clear that the high temperature will insure the reduction of the protoxide of iron by the carbon of the metal, not to mention the other foreign elements.

6. I have calculated the temperature of combustion of the above several kinds of gases without reference to the purpose to which their heat is to be applied; we will now take the practical case of a metal bath containing 10 tons of iron, and we will inquire "to what temperature the carbonic oxide blown in during two hours will raise such a mass of metal?"

We will take, first in order, the gas containing 75 per cent. of carbonic oxide, and 25 per cent. of nitrogen, of which we found that 5,950 lbs. are injected in two hours. We suppose that the gas and the air have an initial temperature of 500 deg., and the molten iron an initial temperature of 1,400 deg.

M. Scheinz, C. E., of Strasburg has fortunately given a series of determinations of the specific heat of two typical kinds of cast metal for every 100 deg., from 1,150 to 2,000 deg. The mean of these at 2,000 deg. (the least favorable values of the author's method) is 1,914.

The kilogramme is little more than $2\frac{1}{5}$ lbs. English, so that if we take $\frac{5}{11}$ ths of the above weight of 59.50 lbs., we shall have 2,704.54 kilo.$=W_1$ (above) and $W\frac{1}{3}$=the combined nitrogen is 901.50 kilos. The oxygen for combustion will be $\frac{4}{7}$ W_1 or the CO_2 will be $\frac{11}{7}$ W_1=4,249 kilos. The nitrogen due to this oxygen in the air will be 5,130.42 kilos., the total oxygen will therefore be 6,031.92 kilos. With the above data we find as follows:—

Specific heat of CO_2 due to 1°........	$2{,}704 \times \frac{11}{7} \times .216$	917.784
Ditto.	N $6{,}031.92 \times .244$	1,471.788
10,000 kilos. of Fe.	$10{,}181 \times 1{,}914$	1,948.643
Total specific heat for 1°......		4,338.215

Calories due to CO	2,704.54 × 2,400°	6,490,896.000
Ditto. CO_2	917.784 × 500°	458,892.000
Ditto. N	1.471.788 × 500°	753,894.000
Ditto Fe.	1,948.643 × 1,400°	2.728.100.000
Total calories................		10,371,782.000

If we divide the latter by the former, we obtain as the common temperature of the metal bath, and the products of combustion after two hours operation, 2,398 C.

Now, we do not require so great a heat as this. A temperature a little above the melting point of malleable iron, say 2,150 deg. C. (taking the numbers of Plattner), would be amply sufficient to insure the fluidity of malleable iron or homogeneous iron, and, during the increase of heat up to that point, the reduction of the protoxide of iron in the ores employed. This reduction begins to be sensible at 650 deg. in the blast furnace.

7. We are led by this result to inquire what quantity of carbonic oxide, and what duration of the operation would suffice to give us this temperature of 2,150 deg. C.

In order to arrive at the solution of this question we must take the inverse of the preceding problem, and, assuming as an unknown quantity the quantity of gas required, proceed to determine its value by means of the preceding data and its relation to the temperature supposed.

Let then t be the number of kilos. of the gas required to raise 10,000 kilos. from 1,400° to 2,150°, with a gas of this composition where t represents the carbonic oxide contained in the weight $t + \frac{t}{3}$ of the gas.

These t of CO give 2,400 t calories or units of heat. They require of oxygen to burn them $\frac{8t}{14} = \frac{4t}{7}$ forming $\frac{11t}{7}$ of CO_2. The nitrogen of the gas is $\frac{t}{3}$, that due to the oxygen of the air is $\frac{77}{23} \times \frac{4t}{7} = \frac{44t}{23}$, so that the total nitrogen will be $\frac{t}{3} + \frac{44t}{23}$. For a rise of 1° of temperature the specific heat will be—

Of $\frac{11t}{7}$ kilos. of CO_2.... $\frac{11t}{7} \times .216 = .339\,t.$

Of $\frac{44t}{23}$ ditto N.... $\frac{44t}{23} \times .244 = .475\,t.$

Of $\frac{t}{3}$ ditto N .... $\frac{t}{3} \times .244 = .081\,t.$

Sum.................... .... $.895\,t.$

10,000 kilos. of metal—10,000 × .1,914 =1,914, making the total specific heat due to a rise of 1° in the aggregate of products and metal $1{,}914 + .895\,t$. (1.)

For the calories we have:—

From CO...................... $2{,}400\,t$

$$\left.\begin{array}{ll} \frac{11t}{7}\ CO_2 & \text{at } 500^\circ \\ \frac{44t}{23}\ N & \text{ditto} \\ \frac{t}{3}\ N & \text{ditto} \end{array}\right\} \ldots\ldots\ldots\ldots\ 447.500\,t$$

From 10,000 kilos. of metal at 1,400°—10,000 × 1,400° × .1,914 = 2,679,600.

Total calories—$2{,}847.500\,t + 2{,}679{,}600$. (2.)

If we divide (2) by (1) we have the temperature t° of the bath and products of combustion:—

$$t^0 = \frac{2{,}679{,}600 + 2.847.500\,t}{1{,}914 + .895\,t} = 2{,}150^\circ.$$

From this equation we find $t = 1{,}554$ kilos., and the total gas is $t \times \frac{t}{3} = 2{,}072$ kilos. The time required for the injection of this 1,554 kilos. is 2 hours $\times \frac{1554}{2704} = 1$ hour 17 min. 28 secs.

8. Let us lastly take the case of pure carbonic oxide. The weight injected in two hours will be found to be 6,797 lbs. avoirdupois, or somewhat above three tons. This is equal to about 3,090 kilos. in two hours. Let us, as before, suppose that we require t kilos. to raise 10,000 kilos. of metal from 1,400° to 2,150°, then the time required for this will be $\frac{2t}{3090}$ hours. The statement of the analysis will be as follows:—t kilos. C O give out 2,400 t calories or units of heat, requiring $\frac{8t}{14} = \frac{4t}{7}$ kilos. of oxygen to burn it, and forming $\frac{11t}{7}$ kilos. of CO_2. As the C O is at 500°, and the air also, the specific heat of $\frac{11t}{7}$ kilos. of $C\,O_2$ will be $\frac{11t}{7} \times 500 \times .2.6$ or $\frac{11t}{7} \times 1{,}000 \times 108 = 169.714\,t$. The $\frac{4t}{7}$ kilos. of O import $\frac{77}{23} \times \frac{4t}{7}$ of nitrogen $= \frac{44t}{23}$, which at 500° gives a specific heat of $\frac{44}{23} \times 500 \times .244\,t = 44 \times 1{,}000 \times .122\,t = 233.400\,t$. At 1,400°, 10,000 kilos. of cast-iron have $1{,}400° \times 10{,}000 \times .1.914$ of specific heat $= 2{,}679{,}600$. We have, therefore, of calories—

Due to C O........................	2,400 t.
" $C\,O_2$ at 500°................	169.714 t.
" N at 500°..............	333.400 t.
10,000 kilos. of Fe at 1,400°......	2,679,600 t.
Total calories = 2,863.114 t +	2,679,600

In rising by 1° we have of specific heat in—

$\frac{11}{7}$ kilos of $C\,O_2$........	$\frac{11}{7} \times .216$.........	.339
$\frac{44}{23}$ " " N..........	$\frac{44}{23} \times .244$.......	.475
		.814

∴ t kilos. will have .814 t; 10,000 kilos. of iron in rising 1° take $10{,}000 \times 1{,}914 = 1{,}914$ of specific heat.

If, then, we divide the total calories above by $.814\,t \times 1{,}914$, we shall, as in the last case, have the common temperature of the products of combustion and of the iron, which we assume to be 2,150°. This gives us the equation in t:—

$$\frac{2679.600 + 2863\ 114\,t.}{814\,t. + 1{,}914} = 2.150°.$$

whence it is found to be 1,290 kilos, nearly. The time required to inject this quantity will be $\frac{2}{3090}$ hours $\times$ 1,290, or a little more than 50 minutes.

At this point it is necessary to remark that the extreme heat of 2,150 deg. will be required only towards the end of the operation, when the carbon of the metal is nearly all taken up, and the metal is the least fusible. A temperature of less than 1,400 deg. will suffice to oxidize the silicium, the phosphorus, and the sulphur, and to reduce the protoxide of iron by the action of the carbon.

We shall revert to the results obtained in the last two cases when we come to calculate the cost in gas per ton of produce. Assuming that the above analysis and description of the process and of its attendant phenomena have established the soundness of the physical and chemical part of the process, it remains to consider it in the economical and commercial point of view. A finery hearth of 10 ft. by 5 area, with a depth of metal equal to the average depth of a charge in a Bessemer converter, would allow of the treatment of 10 tons of metal at a heat. Two hours were assumed as the possible duration of this treatment, but it has just been seen that, as regards the heat, from less than one hour to one hour 20 min. is quite sufficient. In practice, we should commence with a degree of heat little, if any, above the heat at which the charge was run out from the cupola into the finery, and raise it by degrees, as should become necessary, to the full development of the reactions employed.

Two methods would have been selected for producing the carbonic oxide gas required, and a third is under consideration. The first is the calcination of broken limestone in close retorts by means of waste gases, and the conversion of the carbonic acid gas evolved into carbonic oxide in connected retorts containing anthracite coal or pure clean coke. When there are blast-furnaces, calcined lime is obviously beneficial as well as economical, were it only that it would prevent the cooling of the furnace by its change of volume in becoming changed into carbonic oxide, and by its own change from the solid in the stone to the aeriform state which must take place somewhere with the absorption of latent heat. For the rest, it can be more cheaply calcined in retorts with the waste gases than in the ordinary limekiln.

A second mode is the employment of the gas produced by passing highly heated steam over incandescent coke or anthracite coal. The hydrogen contained in such gas, however, limits the proportion in which it may be safely mixed with cupola or other gases, while the vapor of water formed by its combination with oxygen, or combustion, with its great specific heat, would reduce the temperature.

Estimate of the probable cost of carbonic oxide produced by converting the carbonic acid gas of limestone calcined in retorts heated with waste gases, and passed through adjoining retorts, containing anthracite coal or coke.

The limestone contains — lime, 54.10; carbonic acid, 42.20; and it requires about two hours for its complete calcination. The cost of the limestone, labor, etc., are paid by the lime produced. One ton of limestone yields $\frac{42.2}{100} \times 20$ cwt., or 8.44 cwt. of $C\,O_2$. To convert this 8.44 cwt. of $C\,O_2$ into C O, we require $\frac{6}{22} \times 8.44 = 2.30$ cwt. of carbon, forming 10.70 cwt. of C O. To yield this 2.30 cwt. of carbon, we require of anthracite coal (91.44 per cent. of carbon) 2.62 cwt., say 275 cwt. Thus our amount stands—

	s.	d.
8.44 cwt. of $C\,O_2$	0	0
2.75 cwt. of anthracite at 12s. per ton....	1	8
Two hours' labor, 1 man to 4 retorts	0	10
Wear and general expenses	0	2
Cost of 10.74 cwt....	2	8
Or about 5s. per ton.		

In forming this gas of 75 per cent. CO. and 25 per cent. N., we employ 58.745 cwt. of pure C O and 22.362 cwt. of cupola gas. The latter gas contains only 34.42 per cent. of C O, or 7.67 cwt. of pure C O. The total C O due to both sources will be 66.41 cwts. of which the pure C O is 58.74. We must, therefore, take $\frac{58.74}{66.41}$ of the 1,554 kilos. of C O, or 3,419 lbs. av., as that part which costs 5s. per ton. This amounts to 3,024 lbs., which, at 5s. per 2,240 lbs., amounts to 6s. 9¼ d., being 81.25d.

If, now, we divide by 10 the number of tons treated at a heat, we find the cost per ton of iron balls to be as nearly as possible 8d. per ton. The cost of melting is 3½ cwt. at 12s. per 20 cwt., or not quite 2s. 2d., so that the total cost of fuel is 2s. 10d. per ton of balls or blooms. It is premature to offer an estimate of the cost of labor, but allowing liberally for one engineer, one sub-engineer, one laborer, and two head finers with two aids, we find the total cost per heat of 10 tons to be 2s. 6d., or 3d. per ton of metal ready for balling. To this have to be added the cost of the iron ores and that of caustic soda, which latter, for the worst metal, is now 7s.* per ton; the ores costing about 9s. 6d † This is a total of 19s. 7d. per ton of metal balls. Against this we have to set the gain in produce of 20 per cent., or from 4 to 5 cwt. of iron (the produce of the iron ore employed to oxidize the impurities and the carbon of the metal), which, at only 6s. per cwt., is from 24s. to 30s. In puddling we have coal 15s.; labor, per ton, 12s.; fettling, at least 3s., with other expenses, amounting in all to above 30s.; so that, even with the present high prices, there is a saving of not less than 10s. a ton, independent of any gain in produce, or any question of quality and price. Moreover, this is the cost of common impure metal, which cannot be made to yield good iron at all in the puddling furnace. Good metal requires very little soda, and only iron ore enough to discharge the carbon (about 3s. 6d. cwt.) at some 5s. per ton, the gain in produce being 5½ cwt. per 20 of metal. It must be distinctly understood, therefore, that all that part of the above cost per ton which exceeds 2s. 10d. for labor and gas, and 5s. for iron ore to take up the carbon (a total of 7s. 10d.), is laid out solely for the purpose of making good bar iron out of bad and intractable metal without loss in yield.

The cost per ton of carbonic oxide prepared by the third method under the author's consideration is 6s. 2d. The cost of its consumption (2,838 lbs.) per ton of produce is about 9½d., and adding to this 2s. 2d. for the melting, makes the total cost of fuel per ton of iron about 3s. To this the preceding remarks equally apply. It might seem, at first, that this cost of preparing carbonic oxide in retorts is too low. It is necessary, therefore, to state that all the materials for making the gas will be charged into the retorts by machinery of very simple construction, which dispenses with manual labor.

The materials, being prepared for the retorts, descend through a hopper into a long

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* Exceptionally high; it was only 3s. 6d. in 1870.

† At present high prices.

gutter, furnished with apertures above the retorts, which apertures may be closed at will. In this gutter an archimedean screw, shaped like a flat-wormed corkscrew, revolves and carries forward to the apertures the materials, which drop through into the retorts. The retorts are so constructed as to admit of being closed by a mechanical movement, and of being discharged similarly. With such an apparatus two men may attend to a hundred retorts.

We may illustrate as follows the gain in the yield of 20 cwt. of metal:—

1. The usual loss of 8 to 10 per 100 in puddling (say 8) is 1.6 cwt., which is saved. The metal containing 3 per cent. of carbon, this requires (it being on 20 cwt. 6 cwt.) $\frac{3}{5} \times \frac{8}{6}$ cwt. of oxygen to form carbonic oxide, or $\frac{4}{5}$ cwt. The protoxide contains in nine parts, two of oxygen and seven of iron. If then x be the weight of it required, we must have $\frac{2x}{9} = \frac{4}{5}$, or $x = 3.6$ cwt., which, at 30s. a ton, is 5s. $4\frac{3}{4}$d. The iron reduced from this protoxide will be $\frac{7}{9} \times 3.6$, or 2.8 cwt. This added to 1.6 makes a total gain of 4 4 cwt.

Only the richest and purest ores are to be used, but still a small allowance is to be made for earthy matter; this, at 10 per cent., would be 36 cwt. In fact, it would rarely exceed five per cent., so that if we allow 4 cwt. it would be ample, and this leaves a clear gain of 4 cwt.

If we suppose in the ores which contain much silicium, phosphorus, etc., that these elements, upon their oxidation, reduce the iron ore, the increase of yield would be larger. The increase above estimated cannot be unreasonably large, for Mr. Danks claims to have increased the yield by 15 per cent., which is 3 cwt. at least. There cannot, it is submitted, be much doubt that at so great a heat a sensible quantity of sodium would be reduced and thrown into the metal. This would, as Baron Gruner and Professor Miller have suggested, have a powerful effect in purifying the iron in the re-heating operation.

Much, however, has yet to be learned as to the behavior of the iron, of its impurities, and of the reactions to which it would be submitted at these high temperatures; but there is good ground for hope. Mr. Bessemer is said to have tried the nitrate of soda with his air blast; but Baron Gruner states that in the presence of fire-brick this is quite illusory as regards the expulsion of phosphorus, in fact a pure waste of the reagent.

It has been stated above that the iron may be " balled "by machinery when it is "coming to nature." This observation, however, had reference much more to the possible preference of the iron-master than to any supposed necessity for the operation. The fact is that the iron at so high a temperature, though malleable, remains in fusion, so that it may be cast into blooms ready for the hammer and the rolls, when sufficiently set by diminution of the temperature. This process, being nearly mechanical, would be far less costly than that of balling, while the iron would be free from scoriæ and " cleaner " (in the phrase of the trade). In truth, the whole process is chemical and mechanical from beginning to end.

It is hardly necessary to add that the crystalline structure of the metal will be broken up by the hammer and the rolls and replaced by the fibrous.

NOTE I.—Since the above was written the author has found two ores of iron admirably suited to this process—the " Marbella " magnetic ore, and the " Iserine," or Titaniferous magnetic ore, in the state of a fine sand, both of which may be obtained to almost any amount at about 30s. per ton. The " Marbella " would be greatly improved if ground up with one-fourth of its weight in " Ilmenite," in which the oxide of Titanium attains to 40 per cent.

NOTE II.—If it be the object to obtain very superior iron or steel, for special purposes, from cast iron free from impurities, nitrate of soda may be employed. This being injected with the blast (which in such case need not be heated) in small quantities at a time would have all the effect of the Heaton converter, without its waste of the nitre. The cost per ton of iron would be trifling, such metal being practically free from sulphur and phosphorus.

DISCOVERY OF COAL NEAR BAGDAD.—A coal mine has been discovered in the Bagdad district, between Yezireh and Zeto. According to the report of M. Mongel, engineer to the Viceroyalty, the formation extends over a length of more then seven kilometres, with a breadth of from 150 to 200 metres. Eighty-four tons were got out during the first three weeks of working.

HEAVY GOODS LOCOMOTIVES.

From "Engineering."

The extremely heavy character of the goods traffic to be carried on some of the leading Continental railways, and particularly on some of the mountain lines more recently constructed, has called into existence several types of powerful locomotives differing materially from any in use in this country. The Vienna Exhibition contained many examples of such types, and as a large proportion of these have already been illustrated and described in this journal, our readers must be familiar with the chief modes by which the Continental locomotive engineers have endeavored to solve the problem before them, namely, how best to produce locomotives of exceptionally great tractive power. Our object in the present article is to speak of some of these plans, and to compare them with other modes of attaining the same end.

In the majority of cases the locomotives built for exceptionally heavy work on the Continent are eight wheeled, all wheels being coupled, and all axles being under the barrel of the boiler. The cylinders are outside, and in a large number of instances the engines are built upon Hall's system, and have outside frames and outside cranks. The wheel base is kept as short as possible, and flexibility is given by allowing lateral play to the trailing—or in some cases both leading and trailing—axles. Such, in broad terms, are the leading characteristics of the exceptionally heavy goods engines now made on the Continent, and it is undeniable that such engines do a large amount of work at slow speeds in a fairly satisfactory way. Notwithstanding this, however, it is, we think, equally undeniable that they possess many grave defects which may be avoided by adopting another system of construction.

In the first place the necessity which exists for maintaining a short wheel base has led to the practice of putting all the axles under the barrel of the boiler, the result being an excessive length of boiler barrels and of tubes—tubes 15 ft. and 15 ft. 6 in. long being common, whilst, in some cases, the length reaches 16 ft. 6 in. To make the engines ride more easily, also, compensating beams are generally being introduced between the driving and trailing springs, and not unfrequently between the springs of the leading and second wheels also, and these compensating beams, although undoubtedly useful for reducing shocks, tend in some cases to reduce the control of the longitudinal oscillations or pitching motion to which the excessive overhang of the engines gives rise. Considering that the normal load on a pair of wheels in one of these heavy engines is generally between 12 and 13 tons, it is evident that the oscillations and augmentations of this load, due to insufficiently controlled pitching motion, must have a most serious effect upon the road, and most materially increase the cost of maintenance of the latter.

The true remedy for this state of things is, as we have stated on former occasions, the adoption of the double-bogie system. Once let that system be adopted, and we get rid of all difficulties such as those to which we have just alluded. We can lengthen the wheel base of the engine to any desired extent, so as to obtain longitudinal steadiness, while, at the same time, we retain the utmost facility for traversing sharp curves, and especially we get rid of those variations of load per wheel due to pitching, which, in engines with great overhang, play such havoc with the permanent way. In a double-bogie engine the weight of all parts above the bogie is transmitted to the bogie pins, and is distributed over the wheels of the bogies in the proportions determined by the positions of those pins, the distribution thus effected being practically constant under all circumstances, and being only modified to an immaterial extent by the motion of the reciprocating parts of the working gear. The advantages of this state of affairs are even greater than may at first appear. If the construction of an engine is such that the normal load per axle is liable to be sometimes increased by the pitching action to the extent of 30 or 40 per cent., then in fixing the normal load this circumstance must be allowed for, and the load made less than it might be if its constancy could be insured. The double-bogie system, as we have seen, gives this constancy, and hence it follows that in an engine constructed on that system a greater load may be carried upon each pair of wheels than would be safe under other circumstances. On the other hand, also, the double-bogie system gives every facility for decreasing the load per wheel if desired. Practically, it is found undesirable to couple more than four pairs of wheels; but if we divide our power between two groups, each with its own pair of cylinders, we at once double our power of distributing the load, and can, if necessary, divide that load between sixteen wheels instead of eight without incurring difficulties. Taking into account the constancy of the distribution of the load already alluded to, however, we are inclined to believe that it will be on but very rare occasions necessary to resort to eight-coupled bogies, a maximum of six wheels per bogie, or twelve in all, being, we think, all that is likely to be required even for mountain locomotives, at all events for many years to come.

Another advantage of the double-bogie system attendant upon the features which we have jnst pointed out, is that it enables us to produce tank engines for the very heaviest classes of work, and capable of carrying large supplies of water and fuel. The eight-coupled type of engine so much favored on the Continent is quite unadapted for transformation into a tank engine, as the load per wheel in those engines is already as great as it is safe to carry under such conditions, and hence they are made generally with a light class of tender, the weight of which, however, is always, and necessarily so, greater than that of the tanks and coal bunkers required to make the double-bogie engine carry its own fuel and water. As every ton saved in the weight of an engine—or of an engine and tender combined, if a tender is used—without decreasing its efficiency, means so much added to the useful load it is capable of hauling, the importance of this is evident.

It has been urged in some quarters that it is a mistake to carry the fuel and water on engines intended for heavy work on inclines, as the weight available for adhesion becomes reduced as the incline is mounted; the fallacy of such an argument is almost self-evident; but as the objection has been seriously advanced, it may be worth while to say a few words respecting it. It will, we think, be conceded that for very low speeds, such as are resorted to on heavy gradients, engines may be constructed in which the hauling power is limited only by the adhesion available. In other words, the boiler and cylinder power may at these low speeds always be in excess of the adhesion. This being so, it is desirable to turn to account, for increasing the adhesion, the weights of all necessary parts of the engine, amongst which the tanks and fuel bunkers must evidently be counted. If these parts be mounted on separate wheels, and thus formed into a tender, they simply increase the load to be drawn, and reduce by so much the weight of train which the engine is capable of hauling. If, on the other hand, they are carried on the engine itself, they increase its hauling power to the extent due to their own weight, and this whether they are full or empty.

There is another point in which the double-bogie system offers an important advantage, and that is, in the facility it affords for the construction of very powerful boilers carrying high pressures of steam. An examination of the large goods locomotives now being constructed on the Continent will show that the limits of steam-generating power afforded by the ordinary locomotive boiler have practically been reached. Already there are running boilers 5 ft. in diameter—a diameter which is nearly as great as can well be accommodated, while it is one which necessitates the use of very thick plates, or else a reduction of the pressure below that with which the best results are being obtained in this country. It is quite true that 5-ft. boilers may be made to stand far higher pressures than those at which they are now worked, while, of course, if necessary, $\frac{7}{8}$ in. or 1 in. plates could be employed in their construction, just as they are in modern marine boilers. But in the case of locomotive boilers the use of such plates would lead to many difficulties, and we think few locomotive superintendents would care to adopt them. If, now, the double-bogie system be carried out in its integrity, as is done by Mr. Fairlie, the engines being built with a double boiler and central firebox, we at once get rid of all difficulties about boiler power. It is evident, in fact, that this system gives us the means of producing boilers twice as powerful as any ordinary boilers now in use, without increasing the thickness of plates; or, on the other hand, if the present power be retained, it enables us to reduce the diameter of boiler barrels, and to employ plates of a more manageable thickness. It also, as we have frequently pointed out, gives us the advantage of a constant depth of water over the firebox crown, whether the engine is on a level or on gradient, whilst it likewise enables us to increase the fire-grate area to any desirable extent without producing the evils due to overhang.

We have already alluded to the excessive length of tubes employed on many Continental goods engines, and we have pointed out that this is due to the packing of all the wheels under the barrel of the boiler. We have known it urged that this great length of tube is necessitated by the nature of the fuel consumed on many Continental lines, the long tubes being required to obtain a reasonably good evaporative duty from the inferior class of coal available. In other words, it has been stated that the length of the tubes is not a result of the position of the axles, but that the position of the axles has resulted from the necessity for long tubes. This argument is, however, directly negatived by the practice of the engineers by whom these long-tubed engines are built, for on the very lines on which eight-coupled engines with tubes 15 ft. 6 in. to over 16 ft. long are at work, we find also in use six coupled and passenger engines with tubes of the same diameter, but 2 ft. to 3 ft. shorter. As all these engines are using the same fuel, and as longer tubes could certainly be used in the two latter classes of engines, if it was specially desirable, the natural deduction is that the tubes are shortened when circumstances permit of this being done. With the double boiler the tubes can of course be kept with the ordinary proportions of length to diameter. The subject of locomotive boiler proportions for different classes of work and varieties of fuel is, however, one on which much could be said, and as we hope shortly to discuss it in detail, we shall not enter further into it here.

We have necessarily, in the present article, repeated many arguments, which we have advanced on former occasions, and we have done this because we see on all hands an increase in the class of railways on which, of all others, the double-bogie system can be employed with advantageous results. Everywhere there is a tendency to build lines of moderate first cost; this desire to economize on the original outlay leading to the adoption of steeper gradients, sharper curves, and a narrower gauge, besides, in many cases, a lighter type of permanent way. By the adoption of Fairlie engines such lines can be made to accommodate an amount of traffic which is out of the question so long as ordinary locomotives are used, unless, indeed, the latter be employed to a great disadvantage. On mountain lines of more costly construction, or on other railways having to accommodate a very heavy goods traffic, the adoption of the double-bogie system would not only enable an increase to be made in the loads drawn, but would effect a most material reduction in the cost of permanent way maintenance, a matter which is but too often neglected by those having to provide locomotive power. As we have recently had occasion to state, the Fairlie system is no longer an experiment, but an established fact, and it behooves all in charge of such lines as we have mentioned, to learn for themselves the lessons which it teaches on the railways where it is in use.

CORROSIVE EFFECTS OF IMPURE WATER UPON SURFACE-CONDENSER TUBES.

By J. A. HENDERSON, M. E.

Written for Van Nostrand's Magazine.

Having been recently called upon to make an examination into the cause of a corrosion taking place in the tubes of the surface-condenser in use at the "Metropolitan Flour Mills" of Messrs. Hecker & Bro., the matter was taken in hand, and a report written out, of which the present article is essentially an embodiment.

Prior to giving the results of the examination, a short description of the condenser and its circumstances becomes necessary. It is one of Lighthall's manufacture, being of a long and narrow rectangular form, provided with 1,800 $\frac{5}{4}$ in. (external diam.) brass tubes, put in horizontally, and arranged for the water supplied for effecting condensation, to pass inside and the steam outside of the tubes. This condenser is now used solely to obtain a constant supply of distilled water, and so to save a large water rent as well as to prevent the necessity of frequently cleaning the boilers; no air pump is attached and no vacuum carried. The condensation water passing through the tubes, is pumped from the innermost end of one of the East River docks, from which the mills are distant only a few hundred feet, and is rendered visibly impure by the discharge of a sewer having its outlet in this same dock, the impurities being confined not only by there being but slight draught of water, but also by the tidal currents being largely cut off by an adjoining stone division wall, extending out 50 ft. or more from the mouth of the sewer.

The tubes first began to be corroded completely through, some 18 months after the condenser was put in, and have ever since steadily continued to give out, often at the rate of several per week. The leaks become apparent by the presence of quantities of salt in the boilers, and the individual tubes to which they belong have to be renewed, after having been detected by filling the external steam spaces with water, and observing any flow from their ends in the tube-plates, thus involving delay as well as expense and trouble.

In taking up the problem of investigating the definite cause of this corrosion, the first point to be noticed was the actual nature of the perforations in the tubes. The completed holes appear from the outside nearly round in form, and of all sizes up to $\frac{1}{4}$ in. or more in diameter; they seldom occur in greater numbers than 3 or 4 in any one tube, and, as afterwards stated, seem most apt to be situated along the same straight line at the lowest part of its surface.

Several pieces of the perforated tubing were brought away and sawn or split open lengthwise, to examine the internal surface and compare it with the outer. The perforations were found invariably to begin from the inner surface, as pits of partially corroded metal of all depths existed there, while the outer surface remained intact, except in the immediate neighborhood of completed perforations where a drip from within had begun. These internal pits, extending only partway through, although not so apparent at first sight, were readily detected by scraping with a knife, and were very numerous. The action of the water seems, however, to have been by no means confined to them alone, because the whole of the internal surface exhibited traces of similar corrosion, as was indicated not only by its being soft and brittle compared with the outer metal, but by its being perceptibly thinned in many places. In proof of internal corrosion, it was further noticed that the pits, as well as completed holes, if not too much enlarged by leakage, were always largest near the inner surface, where the action first began.

Because of the corrosion thus taking place on those surfaces of the tubes directly in contact with the water used in effecting condensation, and in a much more rapid manner than is the case with the tubes of ordinary marine surface-condensers, having substantially the same construction as the one in these mills, it follows that the trouble under consideration must be due to one or the other of two causes, viz., either the presence of some agent or corrosive substance in the condensing water which is foreign to pure salt water, or the presence of impurities or flaws in the metal of the tubes, having essentially the forms of the pits, perforation, etc., just considered, and more readily attacked by ordinary salt water than the brass commonly used for marine condenser-tubes.

There are no other conceivable causes than those two just mentioned, to account for this example of rapid corrosion. As for galvanic action, aside from the consideration of the nature of the water, the conditions are precisely the same as in many other surface-condensers in use, and in fact such action (which in all probability exists whenever any chemical change is taking place) would be in favor of preserving the tubes at the expense of the cast-iron walls of the condenser, and might further be made use of in preserving both tubes and walls by introducing or suspending in the path of the water, a sufficient quantity of some finely divided metal capable of being acted upon more readily than cast-iron or brass, such for example as thin plates of wrought-iron or zinc. This method of procedure would, however, not be likely to be of much avail in this case of a surface condenser, owing to the mass of water passed through the tubes, and also perhaps to the latter being put in with wooden ferrules and so partially insulated from the iron.

In taking up the last of the two causes previously mentioned as capable of producing this corrosion, it must be stated that the tubes are of a standard New England manufacture, and are furnished to a large portion of the surface condensers used in this country, where they are known to last for a term of years, several times as long as the period of only 18 months in the present case. This in itself directly points out that something other than flaws or impurities in the brass must be the cause of the trouble, and this last statement is verified by the fact that as the tubes are seamless and have to be drawn, imperfections could never exist of forms like the pits and holes here existing, nor would they in any probability be wholly confined to the interior of the tubes. In final proof of the metallic composition of the tubes being what it should be, the results of a qualitative analysis of the corroded brass indicated the presence of no other metals in appreciable quantities besides the copper and zinc, than very faint traces of iron and tin, the former probably being deposited as oxide from the water, and the latter constituting the remnants of the internal tinning.

Independently, therefore, of any further examination, it is a priori to be concluded with almost certainty that the destructive agent is contained in the condensation water, and that it is something not met with in the relatively pure salt water used in the supply for surface condensers of vessels at sea.

The conclusion just given was further confirmed by the results of chemical examinations of the deposit of scale and corroded metal scraped from within the tubes, and of several samples of the condensation water.

The analysis of the scrapings from the tubes was made with the more special object of detecting the presence of those acids or other non-metallic elements, in combination with the brass, and derived from the water, only of course those whose compounds with copper or zinc are practically insoluble being expected to occur in any quantity. The following substances were found present, besides the metals in the brass, and some mud containing a little lime: sulphuretted hydrogen (in small quantity, existing as sulphide), sulphuric, acetic (only traces) and carbonic acids, and ammonia, all of which were combined either with the copper or zinc; except the sulphuric acid, which was due to a slight deposit of sulphate of calcium (boiler scale); and were to be anticipated as existing in some form of combination in the condensation water. As, besides, this combined and inert (as far as corrosion is concerned) sulphuric acid (in solution as well as in carbonate of calcium) is the only one of all these that exists in pure sea water, the sulphuretted hydrogen, ammonia, and acetic acid must have constituted a portion if not the whole of the substances whose presence as impurities in the water, is the cause of the corrosion that we are considering.

The samples of condensation water analyzed were taken from the ends of the condenser just outside of the tube plates, and contained a good deal of a heavy organic sediment, that in time collects there. There was found, by the analysis, in addition to a somewhat reduced quantity of the dissolved constituents of common salt water, and the black, insoluble, and but partially decomposed organic matter, sulphuretted hydrogen, mainly combined with this sediment; ammonia, in sufficient excess to retain an alkaline reaction over any acids present; free carbonic acid, in greater proportion than in pure salt water, together with traces of acetic, nitric, and phosphoric acids, existing as acetates, nitrates, etc., the whole of which are to be traced to the decomposing matter discharged by the sewer into the dock from which the water is derived.

All of these substances having already been found in combination with the brass of the tubes, with the exception of the salts of nitric and phosphoric acids, whose action on the copper and zinc, if taking place at all, would produce soluble compounds that would be washed away, there is left no doubt of the direct cause of the corrosion. It may be that other substances than those found, exist in the water, and help to produce corrosion, but they were not appreciable in quantity, and it is in fact likely that only the sulphuretted hydrogen, or the ammonia with the assistance of the air and carbonic acid in solution, really effected the result.

These conclusions were further corroborated by making up a somewhat dilute and alkaline solution of sulphuretted hydrogen and ammonia, together with relatively small amounts of salts of the other acids found in the analysis, so as to resemble the impure water in composition, but still be of a much stronger nature, and then observing its action upon slips of clean brass. By this solution the slips were tarnished in a few hours, with a black coating of the sulphide of copper and formation of the blue ammoniacal solution of the oxide, the zinc appearing as flakes of the white sulphide. When immersed in some of the impure water from the condenser, the surfaces of similar similar slips were acted on in much the same manner, and especially by the sediment, but it took several days to bring about the result, while, when in the purest salt water to be had in this neighborhood, the action was very much less in the same time.

Although recorded facts concerning the effects of foul dock water upon brass were not to be found, it can be stated as well known, that upon unprotected iron (specially wrought-iron), the action is very injurious, the sulphide of the metal being formed with rapidity, through the presence of the sulphuretted hydrogen. When there is an actual contact with masses of undissolved organic matter, as is the case with the nails, bolts, and other scraps of iron buried in the mud near city docks, the change takes place so rapidly that in a short time they become completely converted into the sulphide, and also retain their original shapes. As this solid organic sediment is known to have the same corrosive action upon lead, notwitstanding the great resistance of this metal to being attacked by many of our most powerful chemical agents, it is probable that the same would be true for the constituents of brass, and that the heavy sediment which appears in the condenser has a good deal to do with increasing the corrosion. As before stated, this contained a good deal more sulphuretted hydrogen than the water itself, and its observed action on the slips of brass was somewhat greater. It was also noticed that the corrosion in the metal mostly occurs on the same side of any one tube, which side is thought to be the bottom one, from the facts that the deposit of sediment and scale was the thickest there, and that the external corrosion from internal leakage was always confined to the immediate vicinity of the holes, thus showing any drip to have fallen directly downwards. This is a further proof of the direct corrosive influence of the sediment. Still another way in which it may indirectly increase the corrosion is by clogging or partially filling up the tubes, thus obstructing the flow of water, allowing the temperature to approach that of the steam, and so aiding by heat the chemical actions taking place in the corrosion. Both of these statements receive further evidence from another fact not hitherto mentioned, that the majority of the faulty tubes were taken from the lower half of the condenser, where the supplied water first enters, and where the most sediment would be apt to be caught or settle out.

Finally, regarding the remedy for the corrosion, having concluded the whole trouble to lie in the dissolved impurities and sediment contained in the condensation water and directly derived from the sewage discharged adjacent to the supply-pipe, the most obvious remedy is one that had already been proposed by Mr. Reaney, the Superintendent of the Mills, viz., to obtain a better quality of water by running out the pipe sufficiently far to clear the stone wall partitioning off the inner end of the dock, and so to catch the fresh tide water. At this point the draught of water is several times greater, being as much as 25 ft. at low tide, a circumstance that should give an opportunity for obtaining water comparatively free from any solid matter, and especially the heavy sediment such as was examined a little above the centre of this draught at low water would be the place at which to locate the nozzle of the supply pipe, as there would still be about 15 ft. to clear sediment, with ample depth from the surface both to clear floating debris and to get cold water.

Even after running out the supply pipe, it is not to be expected that the trouble will immediately and entirely cease unless the whole of the tubes be renewed at the time of making the change, because otherwise a majority of the old tubes, being already corroded nearly through, would give out in a comparatively short space of time, notwithstanding the slower action of the purer tide water.

It may be here mentioned that were it impracticable to reach a supply of water freed from the corrosive sediment appearing to be the more direct cause of trouble, the steam and water might advantageously be made to change places in the condenser, so that the sediment, having to be deposited on the outside of the tubes, would have no chance to obstruct the flow of water, or to collect on the brass.

To make sure of the quality of the water at the proposed locality for the supply pipe, some specimens were subsequently bottled and analyzed for the detection of those injurious constituents found in the previous analyses.

There was present but very little suspended organic matter, which was of quite a different composition from the heavy, black, and sulphurous sediment taken from the condenser, being of a lighter color, much more flocculent, and but little decomposed, as was attested by its containing no appreciable amounts of either sulphuretted hydrogen or ammonia. Neither of these substances was detectable in the filtered water, and it seems in fact probable, according to what has been already noticed, that they never do occur in any quantity except in the immediate neighborhood of solid organic matter while undergoing decomposition. Free carbonic acid existed in considerably smaller proportions than in the water previously examined, the amount being no more than might be expected to be held in solution by common sea water. The salts of phosphoric, nitric, and acetic acids, were still present, but in such minute proportions that although the water was evaporated down to about $\frac{1}{20}$ of its original volume, and the salts are non-volatile while in solution at the boiling point, the tests yielded unsatisfactory results. The testing for traces of impurities in sea water is rendered very difficult and uncertain, owing to the presence of relatively immense quantities of common salt, and the other normal saline constituents, such as chloride of magnesium, sulphate of calcium, etc.

The conclusions previously arrived at need in no way be altered by the results of this last examination, when it is considered that those agents most destructive to the brass of the tubes, the heavy decomposing sediment with its sulphuretted hydrogen and ammonia, were here found completely absent, while at the same time all the other substances likely to have any corrosive effect (over and above those occurring in pure salt water) were in much reduced proportions compared with the water previously analyzed, from the ends of the condenser.

Since the results of the above examination were reported, the general conclusions hitherto arrived at and stated in this article have been acted upon, and the work of renewing the tubes of the condenser and of running out the end of the supply pipe is now being carried out.

This case of corrosion at the Metropolitan Mills shows the necessity of observing the nature of the water to be supplied to surface condensers when located in cities where there is a liability of its contamination with sewerage, and is communicated for publication in the hope that its results may prove to be of practical value to mill owners, or others, either now using or proposing to use surface condensation.

Naval Laboratory,
New York, *Dec.* 4, 1873.

PNEUMATIC TUBES.

From "Engineering."

In consequence of the removal of the Telegraph Department of the General Post Office in London, an important extension of the system of pneumatic tubes was rendered necessary.

To insure economy and efficiency the subject was referred to Mr. R. Sabine, who, as is well known, has given a considerable amount of attention to this subject both here and at Berlin, and than whom perhaps no safer authority upon such a matter could have been consulted. The subject was most carefully gone into by Mr. Sabine, and as the use of pneumatic tubes is yet in its infancy, and may probably meet with increased favor as the facilities which they afford become better known, we purpose giving our readers the benefit of those calculations, which Mr. Sabine has kindly placed at our disposal for that purpose.

The first questions to be considered in connection with this subject are three, viz., 1. The diameters of the tubes to be employed; 2. The pressures best suited for working them; and 3. The engine power.

With regard to the first question, as to the diameter of the tubes, this must, in great measure, in the first instance, be dependent upon the capacity of the carriers for receiving messages. It has, however, been ascertained that a 2¼ in. tube—the minimum diameter which it is proposed should in any case be employed—affords a sufficient carrier capacity for a much greater amount of traffic than the tubes, required for the purposes of the Post Office, are likely to be called upon to perform for some years to come. The question then simply resolves itself into one as to what is the most economical diameter of tube to employ, and of drawing a balance between the advantage of increased speed obtained, with the same effective pressure in a larger, and that of the less engine power necessary for working a smaller tube ; or, when the same speed is obtained in two tubes of different diameters, with different pressures, the question resolves itself into one of the respective utilized engine powers.

Taking then 2¼ and 3 in. lead tubes of the lengths of 1,000, 2,000, and 3,000 yards respectively, and a constant pressure of 10 lbs., carriers would be transmitted through them in the times and with the utilized engine powers shown in the following Table

Length in yards.	2¼-in Lead Tubes.			HP.	Length in yards.	3-in. Lead Tubes.			HP.
	Times of Transit.		Volume of Compressed Air per Minute.			Times of Transit.		Volume of Compressed Air per Minute.	
	min.	sec.	cubic ft.			min.	sec.	cubic ft.	
1000	0	58	85 3	4.4	1000	0	50	175.2	9.1
2000	2	44	60.4	3.1	2000	2	23	123.9	6.4
3000	5	3	49.3	2.6	3000	4	22	101.2	5.2

And with a pressure of 5 lb. with the same lengths and tubes :

1000	1	21	61.0	1.5	1000	1	10	119.6	2.9
2000	3	50	43.2	1 0	2000	3	19	88.5	2.1
3000	7	3	35.2	0.8	3000	6	6	72.3	1 7

From these Tables it is at once apparent that with equal lengths and equal pressures, the speed obtained in a 3 in. tube is only 16 per cent. higher than that in a 2¼ in., whilst an engine power more than double is expended on it. Obviously, therefore, any increase of diameter above that actually necessary to fulfil the requirements of the service is attended with a very serious expenditure of fuel.

We next come to consider the second question above mentioned, namely, the pressures best suited for working. In investigating this point it will be seen that there are three items which have to be balanced, which are as follows : By increasing the pressure (1) at what rate the time of transit is increased ; (2) at what rate the volume of air required per minute is increased ; and (3) at what rate the required horse power is increased. According to the foregoing Tables, a carrier in a 2¼ in. lead tube, 1,000 yards long, takes 81 sec. to pass through with 5 lbs. pressure, whereas, when the pressure is increased to 10 lbs., it goes through in 58 sec. Secondly, a carrier goes through a 3 in. lead tube with 5 lbs. pressure in 70 sec., but gets through in 50 sec. with 10 lbs. pressure. In each case the time saved in transit by employing 10 lbs. instead of 5 lbs. pressure is 30 per cent. Secondly with reference to the increased volume of air which would have to be moved, we find from the same Tables that the 1,000 yards of 2¼ in. tube requires to be supplied with 61 cubic feet of air per minute at 5 lbs. pressure, whereas 85.3 cubic feet per minute would be required when a pressure of 10 lbs. is employed. By doubling the pressure, therefore, we should have to employ 40 per cent. greater volume of compressed air ; and this greater volume would be at double the original pressure (above the atmosphere), which very materially augments the work. This, then, brings us to a consideration of the third item above mentioned, namely, the increased horse power necessary for the development of this increased force. In order to produce 1,000 cubic feet of compressed air per minute, and to force the same into a container, the utilized engine performance is 24.1 horse power, when the air is compressed 5 lbs., and 51.9 horse power when it is compressed 10 lbs. Raising the pressure from 5 lbs. to 10 lbs., therefore, would increase at the same time the engine power, as appears by the above Tables, from 1.5 to 4.4 horse power for the 2¼ in. tube, and from 2.9 to 9.1 horse power for the 3 in. tube ; so that in saving, by double pressure, 30 per cent. of the time of transit, it would be necessary to burn just three times as much fuel. It is quite obvious, therefore, that the tubes should be worked with as low a pressure as is practicable.

From these relations of speed, pressure, and diameter, it is clear that by increasing the diameter to save 16 per cent. of time, it is necessary to spend twice the horse power; and that by increasing the pressure to save 30 per cent. of time, three times the horse power requires to be expended. So that if, to save time of transit, either must be increased, it is advisable to increase the pressure rather than to increase the diameter in designing a line of given length. This may be more clearly seen by a direct comparison of the two tubes which have already served as examples. The 3 in. tube being worked with 5 lbs. and the 2¼ in. with 7 lbs. pressure, would give very nearly equal times of transit, and the volume of air and horse power would be as follows:

Length in yards.	2¼-in. Lead Tubes (7 lb. Pressure).			HP.	Length in yards.	3-in. Lead Tubes (5 lb. Pressure).			HP.
	Times of Transit.		Volume of Compressed Air per Minute.			Times of Transit.		Volume of Compressed Air per Minute.	
	min.	sec.	cubic ft.			min.	sec.	cubic ft.	
1000	1	9	71.9	2 5	1000	1	10	119.6	2 9
2000	3	15	50.9	1.8	2000	3	19	88 5	2.1
3000	6	0	41.5	1.4	3000	6	6	72.3	1 7

In two lead tubes, therefore, of equal length, one 3 in. and the other 2¼ in. in diameter, about the same speed of transit will be obtained in both by employing 5 lbs. to work the 3 in. tube, and 7 lbs. to work the 2¼ in. tube, and in doing so there will be expended in the smaller tube with the higher pressure about 16 per cent. less horse power than in the larger tube with the lower pressure. Hence if the carriers of the 2¼ in. tube be sufficiently capacious for the required traffic, the economy resulting from the employment of the smaller sized tube is obvious.

The 3 in. tube with 10 lbs. pressure is a very unprofitable combination, and should not be employed in practice except upon very long lengths. The question of diameter and pressure, therefore, was reduced, for moderate lengths, to a comparison between the engine powers necessary to work a 2¼ in. tube with an air pressure of 10 lbs. and a vacuum of 6.5 lbs., and 3 in. tubes with a pressure of 7.6 lbs., and a vacuum of 5.475 lbs., the pressure and vacuum being worked together in cases where the traffic is sufficient for the employment of a double line, one line being used for the passage of traffic in either direction. Here, then, the question presents itself, whether it would be better, for the purposes of the Post Office requirements, to take an uniform diameter of tube throughout the whole system now required to be laid down —in which the distances range from 820 to 2,560 yards—or to take 2¼ in. tubes for lengths up to about 1,000 yards, and 3 in. tubes for the greater lengths, so as to render the times of transit more uniform. Some advantage might be gained from a combined system, supposing that the pumps and containers are so arranged that there are always available sufficient volumes of air, at, say, 10 lbs. and 7½ lbs. pressures, and at 6½ and 5½ lbs. vacuum. In order to equalize to some extent the times of transit, the tubes might be arranged and worked as follows:

	Diam.	Pressure.	Vacuum.
	in.	lb.	lb.
Lengths under 1000 yards..	2¼	7½	5½
Lengths between 1000 and 1500 yards	3	7½	5½
Lengths over 1500 yards....	3	10	6½

By this arrangement the times would be between the following limits:

System.	Shortest Line.	Longest Line.
	m. s.	m. s.
1 entire 3 in	0 43	2 19
2 entire 2¼ in	0 44	2 22
3 combined	0 44	2 3

The combined system would therefore reduce the transit time on the longer lengths, the saving on the longest being about 12 per cent. As regards the question of horse power, it may be briefly stated that the final volumes to be provided by the pumps would be as follows:

		lb.	Cubic ft. per minute.
1. Entire 3 in. system.	Pressure	7.6	1341 6
	Vacuum	5 475	3106 9
2. Entire 2¼ in. system.	Pressure	10	986.8
	Vacuum	6.5	1980.4
3. Combined 2¼ in. and 3-in. systems.	Pressure	10	625 8
	"	7 6	373.9
	Vacuum	6.5	1452 6
	"	5.475	1293.3

To produce in the reservoirs one cubic foot of air per minute, at the required effective pressures and vacua, the following work would have to be performed:

For pressure.	7.6 lb..............	0 0381 HP.
	10 lb................	0 0519 HP.
For vacuum	6.5 lb........... ...	0.0283 HP.
	5.475 lb............	0.0239 HP.

And the utilized engine performance requisite to produce air enough to work the proposed new system, and two existing iron lines combined, would be, for

	lb.			Total.
1. Entire 3 in.	7	pres,	1341.6 × 0.0381 = 51.1	= 125.4 HP.
	4.475	vac.,	5106 9 × 0.0239 = 74.3	
2. Entire 2¼ in.	10	pres,	986.8 × 0.0519 = 51 7	= 107.7 HP.
	6.5	vac.,	1980.4 × 0.0283 = 56.0	
3. Combined 2¼ in. and 3-in. systems.	10	pres,	625.8 × 0.0519 = 32.5	= 126.4 HP.
	7.6	"	573.9 × 0.0381 = 21.9	
	6.5	vac.,	1452.6 × 0.0283 = 41.1	
	5.475	"	1293.3 × 0.0239 = 30.9	

In a series of experiments made on the 21st February, 1872, several of the pipes were left open at Telegraph street, both for pressure and vacuum, whilst indicator diagrams were taken of the engine and the pumps. The result, in so far as it bears upon the question of engine power, was, that in the most unfavorable instance the indicated engine power was 43 per cent. more than the sum of the powers indicated as being utilized in the pumps; this 43 per cent. being, of course, expended in friction and other unavoidable sources of loss of power. By increasing by 43 per cent. the utilized horse powers above calculated, we shall have

For the 3-in. system..... (125.4+43 per ct) =179 HP.
For the 2¼-in. system.... (107.7+43 per ct.) =150 HP.
For the combined systems (126.4+43 per ct.) =181 HP.

required for the three systems respectively.

From this it appears that the entire 3 in. system and the combined system would cost about equal engine powers, whilst an entire 2¼ in. system would require about 14 per cent. less power than either of the others to maintain it in action.

It will be important to compare the theoretical deductions arrived at by Mr. Sabine in his report on this subject to the General Post Office authorities, with the results actually obtained by that gentleman during a series of experiments made on the tubes, pumps, and engines at the Central Telegraph station, with the express purpose of ascertaining the degree of accordance between the practical results so obtained and the theoretical formula by which the figures given in our former article were arrived at. The experiments made were as follows:

1. Observations of the times of transit in tubes of different dimensions with different pressures.

2. Experiments to ascertain the velocity of the carriers in different parts of the same tube during a simple transit.

3. Observations of the mechanical performance by the steam engine, and simultaneously of the work indicated by the pumps when a known pressure was obtained in a given number of open tubes.

The tubes selected for the experiment were the following, which are in constant use:

		yds.	in. tube.
1. Telegraph-street to	Baltic Coffee House	570	2¼
2. "	Fenchurch-street	980	2¼
3. "	Founders-court	223	1½
4. "	Gresham House	588	1½

The experiments with the tube to Gresham House failed in consequence of the carriers sticking continually at a curve, which, when it did not entirely stop them, retarded them to such an extent as to render any observation of transit time valueless. In the other tubes the carriers did not stick perceptibly, although a slight retardation at curves probably occurred. The lengths of the tubes given above are, it is believed, only near approximations, and not entirely to be relied upon, the lines having been laid down some years ago, and the lengths of curves and entries not having been exactly measured at the time. Another source of discrepancy between the observed and calculated velocities arose from the fact that the formulæ by which the calculated values were obtained, assume the transverse sections of the tube to be everywhere circular; whereas, in laying these tubes at those points where curves—some of which are probably rather sharp—occur, the lead tubes may have been bent into an oval section, in consequence of which the felt carrier, on arriving at the curve, would be compressed on opposite sides, and thus retarded to a greater or less degree. In order to avoid the pressure being altered by the working of other tubes, the experiments were made during hours when there was no ordinary business being transacted. In order also to keep the pressures as nearly constant as possible at the required values during each observation, one or more tubes had to be kept open, so that the pumps were always doing more work than was required by the carrier whose transit was being observed. In these experiments the pressure and vacuum gauges were inserted just within the mouths of the pipes. The gauges sometimes fluctuated between small limits, and their mean indications were, therefore, taken in the record of the tests. With the pressure experiments the air was pumped into the reservoir, in which the required pressure was obtained. After the carrier was put into the end of the tube the compressed air was turned on, and the carrier shot forward, being impelled to the end of its journey by the compressed air pumped in behind it. With the vacuum experiments on the other hand, the flow of air through the tube was constant, the air being pumped continually out of the reservoir into which the end of the pipe was conducted. The carrier was inserted in the open end of the tube, and was accelerated and carried along by the current. The carriers were those used in the regular service; they were made of felt, sufficiently tight without offering much frictional resistance. With the exception of the gauges, the apparatus used in the observations was very complete. The moments of starting and issuing were recorded automatically on a strip of paper by a Bain's chemical telegraph, which simultaneously recorded seconds from an astronomical clock, and also the revolutions of the engine. New mercurial gauges were ordered for those experiments, but they were not completed in time for use on the occasion of the experiments being carried out.

The results of the first series of experiments with the view of making observations of the times of transit in tubes of different dimensions with different pressures, are shown in the following Table, in which the calculated time of transit is also given for each tube and pressure:

Length of Tube.	Diameter	Effective Pressure.	Transit Times.	
			Observed.	Calculated.
Yards.	in.	lb.	sec.	sec.
980	2¼	9.5	62	57.8
		9.3	60.5	58.4
		9.0	62.0	59.4
		7.0	70.75	67.1
		6¾	68.0	68.3
		6⅝	68.5	69.1
		6½	70.5	69.6
		6.0	80.0 (?)	72.3
		5½	74.75	75.4
223	1½	5	11.5	10.5
		5½	11.0	10.0
			1 .25	
			11.0	
			10.75	
590	2¼	8	29.25	29.4
			29.25	
			30.5	
			30.5	
		7¾	30.25	29.8
		7½	30.50	30.3
			42.5	
		5⅛	35.5	35.3
			29.5	
			29.5	
			31.0	

In the last series of experiments the speeds observed with the $5\frac{1}{2}$ lbs. pressure were very contradictory, varying as much as 43 per cent. This difference was due partly to irregular pressure, but principally to the insensibility of the gauge. The agreement between the calculated and the observed values in the other series of pressure trials, as well as in the following vacuum tests, is sufficiently close to corroborate the theoretical considerations on which the formulæ used in the calculations given in the former part of this paper were based:

Length of Tube.	Diameter.	Effective Vacua.	Transit Times.	
			Observed.	Calculated.
yards.	in.	in. lb.	sec.	sec.
590	2¼	8½=4.17	34.0	36.0
		9½=4.67	34.0	33.5
			31.5	
		9¾=4.78	33.0	33·0

In making the calculations as to speed it was assumed that expansion, although it undoubtedly takes place to some extent behind the carriers in tubes, is so slight that the velocity may be regarded as uniform throughout the whole length; and this view was entirely corroborated in the series of experiments which were undertaken for the purpose of testing this point, in the recorded results of which there was not exhibited any difference of speed within the tube due to expansion, for although a more or less regular increase of speed was observed in some of the experiments, in others, where the carriers were drawn in the reverse direction, the speed decreased towards the end of the journey. This result indicates that the difference of the observed speed of the carriers in different parts of the tube was mainly due to the condition of the interior surface of the section in which it was passing.

Experiments were next undertaken with the engine and pumps, with a view to ascertain how much work the engine was doing, and how much of it was being absorbed by each of the pumps in order to supply a certain number of pipes with a constant stream of compressed and rarefied air. In the first series of these experiments thirteen tubes were left open in connection with the reservoirs. During the time they were left open, and the pumps working regularly, the pressures indicated by the gauges were

Pressure, 1 lb.
Vacuum, 8 in.=3.93 lbs.

whilst the mean indications of the diagrams of the pumps taken during the same experiment were

Pressure, 1.8 lb
Vacuum, 4.25 lbs.

As, however, neither the pressure nor the vacuum could be held quite constant, the difference between the two readings was probably to some extent due to their not having been made simultaneously.

The second series of experiments was made with seven tubes left open at the distant ends. The pressures indicated by the gauge on this occasion were

In the pressure pipes, 6 lbs.
" vacuum " 10½=5.16 lbs.,

and the indicator registered a mean of

Pressure, 4.25 lbs.
Vacuum, 5.16 lbs.

The results of these experiments were concisely as follows:

Series I.

horse power.
Mean calculated performance in pressure pump=1.26
" " vacuum " =7.29
9 55
Indicated by pressure pump..............=1 42
" vacuum " ....=8.24
9 66
Engine cylinder (maximum)..............=11.60

Series II.

Mean calculated performance in pressure pump=3.20
" " vacuum " =6.67
9.87
Indicated by pressure pump................=3.10
" vacuum " ....=9.10
12.20
Engine cylinder (maximum)................=17.7

Only about 70 per cent. of the engine power in the second series was utilized in the pumps, the remaining 30 per cent. being consumed in friction and other channels of loss of power; and although the first series showed more favorably, it is probable that no better relation between lost and utilized power could be depended on with safety.

The indicator diagrams of the pressure pump in both series showed a leakage through the outlet valves back into the cylinder on the return of the piston from both ends. In the diagrams of this pump the outlet valve of the top appears to have leaked most in the first series, whilst in the second series the valve at the bottom was the worst, the loss keeping the back pressure up to nearly 5½ lbs. during ⅕ of the whole stroke, and representing a loss of about 25 per cent. of the work which could have been done on that side of the piston. This pump, having a capacity of 2.78 cubic ft., at 40 revolutions, should have a maximum delivery of 212.4 cubic feet per minute at 1 lb. pressure; whereas the volume of compressed air, according to calculation, was only 165.9 cubic feet at that pressure. At the same rate, this pump might have delivered 174.7 cubic feet per minute at 6 lbs. pressure; whereas the calculation showed that only 137.7 cubic feet at that pressure passed. In each instance, the calculated volume was about 22 per cent. less than the maximum volume which the pressure pump might have delivered. The inlet valves appeared—by the tardy rise of the pressure curve—to have leaked also. The indicator diagrams of the vacuum pump of both series showed that the valve at the top stuck at the commencement of the stroke and opened with a jerk. The diagram at the bottom was very regular, and the remainder of the valves appear to have been in good order; nevertheless, the capacity of the vacuum pump was, at the rate at which it was worked, considerably in excess of the duty which it performed.

From the results of the foregoing investigations, Mr. Sabine draws the general conclusions that, in regard to the proposed extension of the pneumatic tube system in connection with the Postal Telegraph Department:

1. The most economical results will be found from the employment of an entire 2¼ in. lead tube system.

2. The pressures best suited for working are 10 lbs. pressure, 6½ lbs. vacuum for all lengths.

3. The engine power necessary to be provided will be 150 horse power, of which not more than 30 per cent. may be used in internal friction, etc., and the remainder in providing about 1,000 cubic feet of compressed air, and 2,000 cubic feet of rarefied air per minute.

THE ARCHITECTURE OF CHINA.*

From "The Building News"

In that strange college in the Island of Laputa, which Gulliver visited in his travels, he relates, among the seemingly impossible problems on which its inmates were spending their lives in trying to solve, that one was an effort to build a house by beginning at the roof. This, curiously enough, is the Chinese method. The framework of the roof is first made on the ground in the exact spot where the house is to be, and then it is raised up and the pillars are placed below to support it, the walls being afterwards formed by filling up the spaces between the pillars with brick. Putting up a roof in this manner is suggestive of pitching a tent; indeed, it is said that the peculiar curves of a Chinese roof are an imitation of a tent form, and that this is the real origin of Chinese architecture. Such may have been the case, but now the architecture of the country is essentially wooden, and these wooden forms may be found, as in other countries, repeated in stone and marble. Many important buildings are yet wholly of wood, such as the structure on the north altar of the Temple of Heaven, and the great hall of the Ming Tombs—which last, Mr. Simpson said he believed to be one of the finest buildings in China. Stone is largely used for bridges, gateways, and for public works; while ornamental structures in gardens, and balustrades surrounding tombs and important buildings, are generally of marble. Brick may be said to be the principal building material of China. The walls of cities are built of bricks about 12 in. long. For some temples and fine building work, very small grey bricks are used; they are ground perfectly square and all to one size; so exactly is this done, that, when built, one cannot insert the point of a knife between them, and the work produced will rival the finest specimens of work in any other part of the world. Tiles are almost universally used for roofs; in palaces and temples they are often colored and glazed. There are a number of very handsome pailows about Peking, in which glazed tiles or bricks are used, producing a very fine effect, yellow and green being the favorite colors. The Temple on the Wan-sheu-shan, near the Summer Palace, Peking, is, with the exception of a marble base, wholly constructed of beautifully-colored majolica, rich and bright in effect, all covered with ornament and Buddhist figures. This is one of the finest specimens of this kind of work in existence. Close beside it is a very fine temple, all formed of bronze, almost every form of Chinese architecture being repeated very perfectly in that metal. Mr. Simpson then proceeded to describe the buildings of the British Legation in Peking, of which several large detail drawings were exhibited. The building occupied by the Legation belongs to the Duke Leeang, one of the offshoots of the Imperial family. It was called the Foo or Palace of the Duke Leeang, and is a fair specimen of Chinese architecture. All buildings of this kind

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* A paper read before the Royal Institute of British Architects, by Mr. W. Simpson, F. R. G. S.

are placed upon a raised stone platform, with steps for ascent. Some of the stones forming the floor of this building are cut with circular discs as bases for the wooden pillars. The pillars are not inserted; they only rest like the pole of a tent. In more common houses, where no platform has been made, circular stones are placed below the columns so as to preserve the wood from the damp of the ground. All houses are made to face the south; there is no exception to this in palaces and better-class houses, although in the dwellings of the poorer classes it is not always attended to. The usual reason assigned for this is owing to a peculiar deification of wind and water, known as the Fung-Shuie—these words simply meaning wind and water; but they have much to do with everything in China, and control the architect as well as the sexton. A palace like the Duke Leeang's, comprises a series of buildings, each behind the other, towards the north. As the visitor passes through from the south, the successive buildings get richer in material and ornament; but there is no essential difference of constructive character. The more private rooms of a palace are those towards the north. There is only one floor in Chinese houses, and their distinctive feature is that extent of accommodation is derived from the repetition of these halls, and not from stories above or extensions on the side. Houses in India, such as at Delhi and Benares, are quadrangles, with rooms all round looking into a garden in the middle. A Pompeian house is only a variety of this. The Chinese plan is most marked in its difference. In the building occupied by the British Legation, in connection with the first of these halls on the south only a comparatively small space at each end is walled in, indicating that it has only got accommodation for some outer attendants. Passing this, each hall has more enclosed space, and the most northern are walled entirely round. The ground between each is more or less in the form of a garden with shrubs, flowers, and plants. There is still an outer wall, and one may be passing to a very fine palace in Peking, and see nothing but dirt and decay on the outside. One very distinctive feature in Chinese architecture is what, for want of a better name, Mr. Simpson called the "frieze." It reminds one of the bracket capital of Hindoo architecture, and no doubt had a similar origin. It is now a complicated triple succession of small brackets, which project forward, giving increased breadth on the top for the support of the roof. Although evidently constructive in its origin and purpose, it is the most ornamental portion, and its complexity makes it perhaps the most striking feature of Chinese architecture. All buildings with anything like architectural pretensions will be found to have this peculiar frieze. Its origin is evidently wooden; but Mr. Simpson had seen it repeated in stone, marble, majolica, brick, bronze, and iron. The celebrated tombs of the Ming dynasty, which are about 40 miles north of Peking, were next described by Mr. Simpson. A fine road with splendid bridges, now all gone to ruins, formerly communicated with the capital. On approaching the tombs from Peking, the first notable feature was a pailow, of 5 gateways, in fine white marble, much resembling the gateways of the Sanchi tope, in Central India. The wooden origin of its construction was palpable at the first glance. One of the noted features of the Ming Tombs is a long dromos, with colossal stone figures on each side. This strange approach is nearly a mile in length. There are 32 figures in all, 20 of them being animals and 12 are human. They are in pairs, opposite each other, and facing the roadway. The figures are all of stone, and although not executed in what is understood by rude art, yet they are not of a high class of work. At the end of this sculptured avenue the Ming Tombs become visible. They are called the Shi-san-ling, or the Thirteen Tombs (for that is the number of Emperors buried at this place), and they extend for some miles along the base of the hill, which forms an amphitheatre all round. The tomb of Yung-lo, the first of the Mings, buried here, is an earth mound, about half a mile in circumference. There is a retaining wall, crenellated, and about 20 ft. high all round. To the student of Indian architecture this grave heap will be of great interest, as giving almost the exact model of such monuments as the Sanchi and Manikiola topes, which were developments from the tumulus and the cairn. As all graves in China are places where offerings are made, they become, as it were, altars or temples. At an Emperor's tomb a temple is constructed for the ceremonies, and in the case of Yung-lo's tomb it becomes an important addition to the original tumulus. A rectangular space, about 1,200 ft. long by 500 ft. wide, south of the tomb, is enclosed by a wall; within this are a number of buildings, the plan of one of which is exactly that of a "yamun" or palace, suggesting the ancient idea that the tomb, the temple, and the palace were symbolically repetitions of each other. On the top of the wall enclosing the mound, and in a line with other buildings to the south, there is a structure which contains what Mr. Simpson supposed to be the monumental tablet. This tablet or tombstone is a tall block placed erect on the back of a tortoise, as all tombstones erected by Imperial order or permission are. Further south is a wooden pailow or gate, and then a small hall. The next building to the south is the great hall—the finest specimen of Chinese architecture which Mr. Simpson had seen. This building measures 220 ft. by 92 ft. 8 in. The roof is supported by 60 pillars, 16 of which are 60 ft. high and about 11 ft. 4 in. in circumference. The others are about 40 ft. high. The wood is teak, said to have been brought from Borneo, made into a raft, and floated most of the way; but these heavy materials must have entailed a long land-carriage. Although quite four hundred years old, the pillars, in common with the whole of the building, are about as perfect as on the day they were first erected. The raised stone platform, which is the base of Chinese buildings, becomes in the important or imperial edifices a triple terrace, with a low marble balustrade. The purpose of this vast hall seems to have been that of containing the ancestral tablet of Yung-lo, which is of wood, and not above 18 in. or 2 ft. high. Having described others of the Ming Tombs, especially that of Hung-wu, the first of the dynasty, at Nanking, Mr. Simpson referred to the Temple of Heaven, at Peking, of which curious shrine he said that no adequate description yet existed in our own language. Du Halde's account of it gives not the faintest notion of the place, and his plan of it is fanciful and inaccurate. Photographers who have penetrated to the place have always given the north altar as the Temple of Heaven, whereas it is only a portion of it, and not the most important. The Temple of Heaven occupies about a square mile of ground; that is, the outer wall is about four miles round, enclosing a large space which has a park-like appearance, with avenues of trees. Here the animals kept for the sacrifice find grazing. This temple has three enclosures. The threefold division is common to temples all over the East. We have the Tabernacle of Moses and the Temple of Solomon, and the Eastern churches to this day follow this threefold division. The umbrella is an old symbol of dominion and power, and the Chatta of Buddha is triple, implying, no doubt, sovereignty over the "three worlds" which are so often referred to in the ancient Classics of India. One of the most important of the insignia of the Emperor of China is a triple umbrella, and the circular building on the north altar of the Temple of Heaven has a triple roof. The central portion of the Temple of Heaven contains two altars, which are distinguished as the north and south, the latter being the most important part of the temple. Having described these altars, and pointed out how largely symbolism enters into the construction of the building, Mr. Simpson adduced reasons for his theory that the Temple of Heaven was made in imitation of a sepulchral mound. In speaking of "pailows," Mr. Simpson pointed out their striking identity of construction with that of the gateways of the Sanchi tope, the stones being mortised into each other as if they were logs of wood. There is a very fine old arch in the village of Keu-yung-Kwan, in the Nankow pass; its date is said to be about 1345. It is a triumphal monument, erected in memory of a victory. This monument has great importance to philologists, being a sort of Rosetta stone for this part of the world. It has an inscription repeated in six different characters. The first is in Sanscrit, and that is copied phonetically in Thiketan, Mongolian, Ouigour, Neuchih, and Chinese. The Neuchih alphabet was only known by name, but now a complete knowledge of the characters has been framed from this arch. That portion of the Great Wall of China at the north end of the Nankow pass is in very good condition. It is built of solid stone, with brick parapets, and is said to be 1,200 miles long. The wall which forms the enclosure of the city of Peking is much more imposing to the eye than the so-called Great Wall of China. There are 16 miles of it enclosing the Tartar city, and one 9 miles more round the Chinese city. It varies from 30 ft. to 60 ft. wide on the top. It would form a magnificent street, but no one is allowed to go upon it, and the result is that grass and bushes are growing on it like a thick jungle. The bricks of which it is built are 19½ in. long, 9¼ in. broad, and 5 in. thick. Having described some of the pagodas, Mr. Simpson summed up by saying that to one who is intimate with the architecture of India, that of China seems poor in comparison. And yet it is important from its links of connection and as illustrating a similar wooden development, more particularly the bracket, as a wooden piece of construction which became in both cases an ornamental feature of the architecture. The original architecture of India was wooden, like that of China, and we can only guess at what it was by the stone repetitions which are left. In conclusion, Mr. Simpson described the way in which money is raised in China for building purposes. "In the streets of Peking I one day found a man in a sort of wooden sentry box; large nails had been driven into it, so that their points projected through; this prevented the man from leaning against the sides, and the only rest he had was from sitting on a board within. He was a monk, and never seemed to sleep, for he had a string with which he night and day sounded a large sonorous bell every few minutes, as a sort of advertisement of his purpose. This was that the benevolent should come forward with money; each nail represented a sum; when any one paid that sum his name was stuck up on a piece of paper, and the nail was pulled out, making it more comfortable for the hermit within. All the nails represented the necessary amount for the repair of a temple which was close behind. This is a common proceeding for 'raising the wind' for such purposes. I was told that this monk had been two years shut up, and that he would be another year before he got out of his cocoon of nails."

ON THE APPLICATION OF STEEL LINERS TO THE HIGH PRESSURE CYLINDERS OF COMPOUND MARINE ENGINES.*

By Mr. WM. ALLEN.

From "The Engineer."

For some considerable time I have been in the habit of supplying steel-tipped cylinder gauges to the chief engineers of the vessels we engined. This was done for the purpose of determining the exact amount of wear that took place during any given period; and from the data thus obtained from engines ranging from 90 to 300 horse power, I have found that the greatest amount of wear takes place in the high-pressure cylinder, this wear not being equally distributed over the internal surface of the cylinder, but, if I may use the expression, being rather oblique or devious—sometimes being athwartships the cylinder, sometimes at the top, forward, and the bottom, aft, and giving the cylinder the appearance of having some different or softer metal in its composition. I have found this "wear" in several types of compound engines, and generally in the same places. It may be said or inferred as a reason for this wearing of cylinders that the engine centres were not fair, or that they were out of line. This plausible reasoning does not hold good, for the greatest wear exists in the high-pressure cylinder, while the low-pressure cylinder bears the tool marks, and is correct to gauge. Again, the builders of the engines whose cylinders we have gauged have reputational fame for true engine building. I have also found that although the piston rods were carried through the cylinder covers, as a vertical guide to the motion of the piston, still this wear took place, and still in different places of the cylinder's surface. The results of the high-pressure cylinders so wearing in sundry places will be well known to you. I have found that our trial-trip excellence and first voyage small consumption did not continue, and that complaints, more or less loud, were sent by owners that "the consumption was increasing." So flagrant and telling had some of the reflective complainings become to us that I determined to find, if possible, the reason why in a trial trip or first voyage satisfactory results did not continue. In one instance, on a forcible complaint being made, I went to London to investigate the matter. The vessel had just come in from her second China voyage. We had the engines opened out, and could detect nothing as likely to cause a waste of steam, everything being apparently in good

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* Read before the Institute of Engineers and Shipbuilders in Scotland.

order. The boilers were also examined, and found in good order. On questioning the engineer as to the condition of the engine when standing with steam on her, I was led to suspect that steam was passing, and determined on gauging the high-pressure cylinder, telegraphing to the works for the original or boring-out gauge, on receipt of which I found that on one side of the cylinder, and extending nearly half-way down, one-eighth of an inch had been worn away. We put the piston on the bottom, and on applying a straight edge to the internal surface of the cylinder, it was observed that one side of the cylinder, forward, was rounded, the other, aft (or where the ports were), was hollow. Taking out the piston packing ring, I found its thickness to be unequal also. Concluding from this discovery that the increased consumpt was due to a passing or waste of steam, we re-bored the cylinder, and inserted a liner of cast iron, of a hard mixture, and I have now the satisfaction of knowing that the first voyage data is fairly maintained, thereby proving that the deviation was partly, if not wholly, due to the wearing away of the cylinder in sundry places. From this time I began supplying engineers with cylinder gauges, and also to note if such "wearings" were isolated—the results of my observations proving, as before mentioned, that, with several types of compound engines, and by various makers, the same exists. At this period we were casting our high-pressure cylinders jacketed, and of a re-cast mixture of ten of marine scrap, seven of Summerlee No. 3, and three of cold blast. We found that this bored pretty well, not showing soft; yet when under steam and the engine running, it wore freely. I then made our cylinders of a harder mixture, and on the same arrangement, but gained no cessation of unequal wear, rather losing considerably in having two high-pressure cylinders cracked, after being in the vessels one and three months respectively, which, of course, we had to replace at our cost.

About this time, two years ago, a certain *furore* was in the market, or rather the craniums of shipowners, as to steel being "the thing" for propeller blades; and it was rather amusing to see them scratch out of a specification the usual "propeller of cast iron," and substitute "to have steel blades," as if a ship could not be propelled, or the water cut, without a Sheffield blade. I thought we might be in keeping with the spirit of the times, too, by adopting or trying steel, this never-failing immortal steel, "warranted not to break until worn down," as liners of high-pressure cylinder; and with this object in view, and by way of an experiment, I sent a tracing of a shell to Vickers, Sons & Co., Sheffield, giving them a full account of what we wanted, and what we expected from their steel. Their process of casting this steel I am ignorant of, and unfortunately I have not asked them to define it, else this paper might have had some additional interest; but I dare say it will be fully known to you, or the most of you. The shell was for the high-pressure cylinder of a compound engine we were building for the steamship Achilles, of 140 horse power. It is 32 in. diameter, and having a stroke of 33 in. In due course the shell was delivered to us, and presented the appearance of a clean cast, giving a clear, bell-like ring when struck with a hammer. We carefully watched the boring, and can say that it bored very easy. Being of a close, soft-looking grain, we finished it, using soapy water during the last cast, which gave it a smooth, glassy appearance, and not having the veriest blow-hole in it, it bore all the criticism it received from inspecting engineers and others. We were continually having drummed into our ears the experiences of others with steel, and the difficulties to be met with. Some said: "The piston would seize unless there was a brass packing ring fitted!" Others, "That it would wear away the piston." One even went the length of hinting: "We would need a tallow pump attached to the engine for lubricating the steel," and so on, *ad nauseam.* In due course the engine was finished, the liner being fitted into the outer cylinder shell leaving the annular space as the jacket, and the piston was of the ordinary form and make. On getting steam up, we found that "no seizing" took place—everything working well and quietly. We had a trial trip of six hours, still no sounds of tearing were heard to verify the suspicions of the suspicious, and we did not "dose her with tallow." The vessel went her first voyage to Alexandria, thence to Odessa, thence to Dunkirk, and back to Sunderland. The engineer reported from Alexandria that no deviation had occurred with the cylinder. By his gauge it was the same as when fitted. On her return we had the cylinder opened out and gauged by the work's boring-gauge, when it was found to be just the same as when at first bored—in fact, the tool feed marks were still there. The piston packing-ring was in every way as originally fitted. The vessel went another Black Sea voyage, and on again gauging the liner we found it in every respect the same as when fitted. And now, after eighteen months' hard running, no wear has taken place with it, or, as the engineer puts it, "he has not set out a piston spring since he left us." From this experiment it will be seen that steel for liners for compound marine engines can be used with success. In the matter of first cost there is, it is true, an increase over a cast iron liner; but when it is considered that the cast iron liner weighs heavier, and before it can be made to run for two years without wear it must be of a hardness that entails tedious and difficult boring, this cost equals, if it does not exceed, the easy-bored, light, unwearing steel liner supplied at 60s. per cwt.

I have not gone into the causes, or assumed reasonings, which can naturally be brought forward to account for the devious or erratic wearing of the internal surfaces of inverted compound high-pressure cylinders. I am not prepared to say or prove that cast iron, at a certain temperature, and under friction, undergoes any change, so that its nature is to a certain extent weakened or destroyed. I leave these profound solutions to the profound. But this I can say, that such "wearings" do take place and exist in the high-pressure or heated cylinder, while the low-pressure cylinder is virtually intact. I have gauged now some ninety pairs of compound engine cylinders by different makers, some having the jackets cast in, others having hard cast iron liners inserted, and have invariably found a substantiation of my views that the high-pressure cylinder wears soonest, while the low-pressure remains good and true.

From the above cause I attribute in a great measure the tales of increased consumpt which as engine builders we often hear or have sent to us; and I daresay there are few marine engine builders who have not felt the weight of an owner's irate pen glowing beneath an increased consumption of fuel, when the poor engine builder coweringly seeks shelter beneath his suavity of manner, or adopts a conciliatory policy. I have purposely condensed this paper, preferring merely to give you the pith of the experiment without an array of wordy padding or long drawn-out sentences, ending in nothing and meaning the same. But if it can point out a mode of keeping the "grand trial trip data" intact for years, or if it directs your attention to a "wrinkle" in the application of steel, whereby steamship owners can be kept "sweet" over fuel matters, I shall, indeed, consider the time I have spent in making gauges, collecting data, making notes, and in writing this, as well spent.

PEAT.

From "The Journal of the Society of Arts."

As is not uncommon in the economic history of mankind, the scarcity and high price of an article indispensable to human comfort and prosperity have called into existence numerous cheaper substitutes. Since coal reached a famine price, great efforts have been made to produce fuel which, if not altogether equal to coal in compactness and calorific power, might not inadequately supply its place at a lower cost. It is true that the laws of demand and supply have already shown their power by attracting an enormous addition of enterprise and capital to the production of coal. In the north of England old pits are being reclaimed from the water, new borings are in progress, extensive submarine mines have been projected, and general activity prevails. Not less vigor is exhibited in other districts. The famous Silkstone and Barnsley seams are subjected to fresh attacks. Cannock Chase will shortly abound with new collieries, while in South Wales new companies are forming, and new shafts are being sunk almost daily. Within the next two years the output of English coal will probably be enormously increased, but in the meanwhile fuel is at a price which seriously compromises many of the most important departments of industry.

Great attention has been given to the

manufacture of various kinds of artificial fuel. The majority of these are composed of coal-dust mixed with ashes and refuse, and supplied with carbon by the addition of tar or bitumen, mixed in one case with a small percentage of farina. It is impossible to overlook the obvious truth that fuel made from coal refuse must, to a considerable extent, depend upon the coal supply, and sympathize in price with the fluctuations of the coal market, but this remark will not apply to peat, a material drawn from the surface instead of the bowels of the earth, and supplying, without any admixture of foreign matter, fuel of a high quality.

In its crude form, peat has been in use from time immemorial, and probably succeeded wood when the diminution of the primeval forest compelled man to seek for other fuel. Peat, from its greater accessibility, naturally preceded coal as a caloric agent, and although requiring preparatory treatment, was more available to the needs of the early races than coal, which requires the employment of labor and skill to withdraw it from the storehouses of nature. But no sooner had civilization supplied means for the extraction of large quantities of coal, than peat naturally fell into disuse, especially in this island, where abundance of coal on the one hand, and the difficulty of drying peat on the other, contributed to invest coal with extraordinary advantages. Coal, however, is very unequally distributed, and in many countries, notably Ireland, Holland, Westphalia, Bavaria, France, and Italy, peat, in its crude or in its prepared form, has long supplied a large proportion of the fuel of the people.

Arising from the annual growth and decay of marsh plants, peat forms the most recent link in a long chain. Wood and woody fibre are the origin and substance of peat, lignite, common or bituminous coal, and anthracite. These all mark gradual transitions from the vegetation of primeval ages to the anthracite of to-day, and are all compounds of carbon, hydrogen and oxygen, but contain these elements in very different proportions. Peat contains water to a much greater extent than coal, and as this water is, of course, opposed to combustion, its removal is the prime difficulty in the preparation of peat for fuel. Peats vary considerably in the proportion of water contained by them, but it may safely be put down as ranging from 75 to 90 per cent. As this large quantity of water is retained in multitudinous minute cells, great difficulty is experienced in getting rid of the aqueous particles.

As this is the main object of all peat preparation, the drainage of peat bogs assumes great commercial importance. An undrained bog contains about 90 per cent. of water, while a drained one holds about 80 per cent. This difference of 10 per cent. is the difference between success and failure. With equal labor applied to raising the wet peat, the out-put of a drained bog will be exactly double that of one undrained, or twenty per cent. of perfectly dry peat against ten. Not only in the proportion of water contained by them, but in other equally important respects, peats vary very much. In structure, specific weight, and admixture with mineral matter, the product of one bog differs greatly from that of another, and indeed the several strata of the same bog vary widely in quality. Nothing can be more absurd than to speak of peat, either scientifically or commercially, as if it were one uniform substance, and this consideration becomes of great weight when tests and figures are referred to. In all reports of trials the quality of peat and the precise kind of coal used should be distinctly stated, as by trying very superior peat against very inferior coal, results might be arrived at on which it would be very unsafe to rely.

As a general rule, peat improves in proportion to its depth below the surface, owing partly to the more perfect decomposition of the woody fibre, and partly to the pressure of the superincumbent mass towards the bottom of the bog; it is darker in color and denser in composition than towards the top, where it is light-brown in color, and full of imperfectly decomposed fibre. The upper part of a high bog also suffers deterioration by exposure to the air. As peat is formed by the decomposition of successive layers of vegetable matter growing on the surface, bogs grow higher year by year. In Ireland and elsewhere it is customary to divide peat fields into "high" and "low." In ponds, lakes, and sluggish streams, "low" peat is formed of reeds and aquatic grasses. This peat is often of very good quality, is tolerably homogeneous, and is comparatively free, excepting at the surface, from coarse fibre and roots of trees. High peat fields are found on mountain tops, or more frequently in slight depressions in hilly countries, and are principally composed of mosses, and vary very much in quality, from the admixture of small roots, trunks of trees, and other objects preserved by the tannin contained in the peat. Men in armor, in a high state of preservation, have been dug out of the Solway peat mosses; and Mr. Ralph Richard mentions an instance of a Scotch Covenanter having been exhumed from a bog in Dumfriesshire.

Owing to varying conditions of formation, the quality of the peat bogs of the Scottish Highlands varies very greatly. The uppermost portion from 1 to 10 ft. down, according to circumstances, is light and open, and possesses but little heating power. On a hill top the inferior quality of the "flow," as it is called, is very marked owing to the wearing influence of atmospheric agents, which exercise a similar deteriorating power on bituminous coal when that mineral is exposed to their influence for any length of time. Beneath the "flow" is found a stratum of a much closer and denser substance, producing sound fuel, giving a good flame, and yielding a large amount of heat. Beneath this is the most valuable stratum of all. Powerfully compressed by the weight of the two upper layers, and thoroughly protected from the atmosphere, the bottom of the bog approaches much nearer to coal, and, when dried and stacked, becomes hard, black and weighty, burning with a red ash.

It will thus be seen that while the upper and most accessible layers are hardly worth the trouble of preparation, the lower stratum of the majority of "high" peat fields richly rewards any reasonable amount of labor spent in preparing it for the fire.

Unfortunately peat combines with many valuable qualities some very serious defects. Perhaps the greatest of these is its enormous bulk, necessitating so much labor in "winning" and preparing it, as to prove fatal to all commercial venture, but those undertaken under exceptionably favorable circumstances. So far as peat industry has hitherto been prosecuted, cheap labor has been shown to be an indispensable condition of success, not, however, so difficult to fulfil as might appear at the first glance, inasmuch as peat is generally found in the greatest abundance in lonely and unfrequented spots, where such unskilled labor as is to be had can generally be purchased at a low price. Of the quantity of labor required, a clear idea may be formed from the consideration of a few simple facts. Peat in its wet state—as cut from the bog—contains, as has been shown, from 75 to 90 per cent. of water, with which it parts very reluctantly. Therefore, to produce a ton of perfectly dry peat, it would be necessary to raise from 4 to 10 tons of wet material. Practically, however, it has been found impossible to dry turf in the air beyond a certain point. Even when ground, macerated, rubbed down, and compressed by most of the machinery in use, and carefully dried, peat generally retains about 14 or 15 per cent. of water, while crude peat, roughly dried in the sun, contains at least 25 per cent. when apparently "dry," and if used in that condition possesses, as opposed to ordinary coal, a calorific power of 1 to 2, weight for weight. An additional disadvantage exists in the lightness and bulkiness of crude peat; thus 1 to 4 would nearly represent the effect of peat as compared with that of coal, bulk for bulk. A cubic yard of solid coal weighs about a ton, whereas a ton of common turf would, according to quality, occupy from three and a half to four times that space. A moment's reflection on these facts will produce the conviction that rough dried peat can never be available for other than local purposes, inasmuch as, in plain English, it is simply "not worth carriage" to any great distance. From time to time improvements have been introduced in the method of treating peat, with the object of insuring more perfect desiccation and greater weight and compactness. In Ireland, where $\frac{1}{7}$th of the surface, or nearly 3,000,000 of acres, is covered with peat, furnishing the almost universal fuel of the peasantry, by far the greater proportion is prepared in a barbarous manner. Cut with a "slane" into clumsy masses, the turf is spread for drying on the undrained surface of a wet bog. It is then reared in small heaps, often packed far too closely to admit of further desiccation, and is finally built up into large piles. In some districts, however, a superior description is made. This is known as "hand turf," "foot turf," and "stone turf," and is made of block peat taken from the bottom of the bog, "footed" into mud, shaped by hand, and dried, when it acquires great solidity. In Holland and the Netherlands a somewhat similar course is pursued. As much of the peat lies under water, it is raised by dredging, conveyed to a kneading and treading floor, where it is freed from roots and other foreign substances, and is subjected to a kneading operation by workmen, who, aided by pieces of board attached under their feet, break it up, and tread it down into a uniform mass of peat pulp. This is spread on the drying ground, and after undergoing a further treading and levelling process, is shaped into a stratum about 8 or 10 in. in thickness. This is cut up into bricks, allowed to remain on its bed to shrink, until firm enough to be handled, and is then made into small piles for drying. The spreading ground, which receives the kneaded peat, is carefully levelled, and is strewn over with a layer of dry reeds or sedge, which facilitates the escape of moisture. Both the Dutch kneaded and the Irish "footed" peat are greatly superior to the crude turf, but innumerable attempts have been made to attain absolute perfection by the aid of machinery, not only in this country, but in Germany, where more than eighty attempts have been made during the present century to render peat-making a commercial success.

The main objects aimed at in the construction of the innumerable peat-making machines that have from time to time been patented, are the reduction of the peat to a homogeneous pulp by maceration, and the extraction of foreign matter. By maceration—breaking up as it does the cellular structure—more perfect desiccation can be achieved than by the hand processes previously alluded to, thereby insuring greater compactness and portability. Almost every kind of cutting and kneading machine has been tried, and a few years ago a plan was tried for rubbing the peat through a sort of colander. Very good results were attained, and excellent peat was made; but for some reason—possibly the expense of production—the venture failed to secure commercial success. From the absence of roots and coarse fibre, and the reduction of the aqueous portion by 10 per cent., the quality of machine-made peat is greatly superior to the rough-dried and hand-made varieties. Compression has been tried, but it has been found that along with the water forced from the peat-pulp were ejected certain valuable constituents, notably a gelatinous substance of great importance to the validity of the fuel. Maceration having been carried far enough, it has generally been found advisable to trust to the natural shrinkage of the peat, during the drying process, to produce sufficient condensation. The difficulty from which escape seems practically impossible is in the drying process. Peat, after due sifting and maceration, could, of course, be dried by artificial heat; but the expense of this process interposes an apparently insuperable bar to its adoption, while the climate with which the British islands are blessed or afflicted—according to opinion—renders any attempt at simple open-air drying practically useless for commercial undertakings on a large scale. Both in England and in Germany drying under sheds has been tried with considerable success, and to the construction of these sheds much ingenuity has been devoted. Shelter from the rain, and the preservation of a thorough circulation of air, are the objects to be achieved in countries where the whole year probably produces not more than a hundred good drying days.

Among the many peat-making systems now in operation, that patented by Mr. Clayton is one of the most recent. On being cut from the bog, the turf is filled into "squeezing trucks." A piston is forced against the peat in the squeezing truck by the aid of a screw and lever, effecting such pressure upon the body of the peat as to force much of the loose or "free" water out of it. The great bulk of the water, however, is locked up in the cellular structure of the fibre, and cannot be got rid of by compression, and the peat is, therefore, next subjected to a masticating process. The trucks run upon a tramway from the peat-bog to the masticating machine, and are lifted from the tramway by hoisting gear. The machine consists of a vertical chamber, in which revolves a shaft, having fixed upon it a series of screw-like blades, the action being somewhat similar to that of an ordinary pug or tempering mill. The rough peat from the squeezing trucks is fed into the hopper of this chamber, and by the action of the blade is broken up and forced downwards into the comminuting apparatus. A screening apparatus may here be introduced when necessary. Connected with this vertical chamber is a horizontal cylinder, which completes the "pulping" operation. This cylinder is fitted with a central revolving shaft, upon which are fixed propelling screws, and also a series of curved arms or discs, so arranged upon it that in their whole length they form a dissected double helix with increasing spiral. Along the bottom of this cylinder, and projecting upwards towards the shaft, are arranged cutting blades of hardened steel, between which the discs pass in their revolution. Thoroughly masticated and reduced to homogeneity during its passage through the machine, the peat is expelled by the continued screw motion in continuous streams on to a special receiver. This consists of a number of rollers, which receive the peat and conduct it to a portable lathed tray, suitably located under the rollers, and carried on fixed wheels, of which there is a continuous forward series. The moving peat imparts motion to the tray, thus pushing it forward from under the rollers until the tray is filled with peat. This is afterwards cut up into bricks, and dried in sheds specially constructed for the purpose. These sheds are made of timber, with louvres all round, and opening in the roof, and differ very materially from the smaller sheds in use in Germany. The machine is driven by an 8 horse-power engine, requires three men and three boys to tend it, and is said to be capable of working up from 60 to 100 tons of wet peat per day.

In Germany, where peat is very well understood and extensively used for railway and other purposes, small hand-machines have long been in use for "macerating" the raw material. For mountain districts, where the manufacture of peat may be pursued with great advantage, these small machines appear to be peculiarly adapted. Six tons of wet peat, producing from a ton to a ton and a half of fuel when dried, can be prepared in these handy little contrivances in a day. An improved hand-machine, specially adapted to the requirements of the Scottish highlands and islands, and of Ireland, has just been perfected by Mr. J. A. Simpson, and combines with the simplicity of the German machine several improvements for insuring complete "mastication." The introduction of hand-machines into districts where the "footing" process now prevails, cannot fail to confer great benefit on the inhabitants, who now waste infinite time in the preparation of their winter stock of fuel.

In Canada an ingenious machine for making short work of peat-bogs was introduced several years ago by Mr. Hodges, well known in connection with the Victoria Bridge at Montreal. A large barge, fitted with suitable apparatus for cutting, cleaning, lifting, and distributing the peat, floats in a channel of water which it forms as it proceeds. Two screws in front cut and draw in the peat, and working in opposite directions, draw the barge forward at the same time. The peat cut and sucked in is subject to a masticating process, and the pulp is ejected through a long telescopic tube over the bog on each side of the channel, where it is left till dry enough to be cut and stacked.

This system appears to require the hot sun of Canada to give it a fair chance of success, and also seems to labor under the disadvantage of attacking mainly the "flow," or upper and least valuable stratum of the peat-field.

The peat-coal, as it is called, recently introduced into this country by M. Challeton de Brughat, is remarkable for its great weight and density. Although "uncompressed," it is hard, heavy, and compact in the extreme. As ordinary condensed peat resembles, when cut, a piece of oak, so does the peat coal resemble coal itself. The compactness of this new fuel, and its greater calorific power, render it very superior to the ordinary preparations of peat; but at the same time it is more costly, as some twenty shillings per ton are talked about as its selling price.

Stated broadly, the position of peat industry on a large scale is as follows:—Inasmuch as most preparations of peat (condensed or uncondensed) only possess, weight for weight, half the calorific power of coal, the successful production of bog-fuel depends upon its being sold for less than half the price of coal. Were it certain that the present price of coal could be maintained for a length of time, the manufacture of peat would offer many allurements to the capitalist. But as many high authorities agree that the influx of labor and capital into the coal trade, and the introduction of coal-cutting machinery, cannot fail, within two or at most four years, to exercise a powerful influence on the market, it is not impossible that peat may once more be severely tried by the competition of its ancient rival. One department of peat industry, however, presents a flattering aspect, be the future price of coal high or low. Peat charcoal can be produced for little more than half the price of wood charcoal, and when used in conjunction with other fuel, affords an admirable agent for the reduction of iron ore. The quality of peat charcoal, easily produced by smothered combustion, is excellent. Being free from sulphur, the quality of iron manufactured with it is of a very high class. In former times it was the practice among the Scottish Highlanders to convert large quantities of black peat into charcoal for the use of smiths in their forges; and modern scientific authorities also attach a high value to peat charcoal, considering it for certain purposes preferable to all other fuel. Presenting an admirable field for enterprise, the manufacture of peat charcoal offers attractions other than those of a purely commercial nature.

It surely seems better, both for contemporary mankind and for posterity, to clear off the peat bogs, and convert unhealthy wastes into cornfields, than to destroy magnificent forests, which are not only grateful to the eye and valuable for innumerable purposes, but—as certain nations have found to their cost—exercise climatic influences of the most important kind.

THE COMPOUND ENGINE.

By JOHN TURNBULL, Jun.

The compound engine—whatever diversity of opinion may be held by engineers and others as to its merits as an economical expansive engine—has attracted towards itself a very considerable share of attention, from the superior results that have been obtained by it in many instances; and it is reasonable to suppose that, when a certain degree of perfection has once been attained in the manufacture of any machine, or economy secured by any new arrangement of its parts, similar machines can be so constructed as to give out the same results, if proper care is taken that the same arrangement and construction is faithfully carried out as in that of the more perfect machine. And when that degree of economy has not been obtained from a compound engine which had reasonably been expected, it would, no doubt, be found, if proper inquiry were made, that the fault lay, not in the principle that had been adopted, but that sufficient skill had not been exercised in properly proportioning the different parts through which the steam had to pass or come in contact on its way from the boiler to the condenser, and that sufficient means had not been employed to prevent or replace any waste of heat from condensation and other causes.

As the compound engine is being now so universally adopted in the Mercantile Marine Service, and a knowledge of its principles absolutely necessary by those engaged in attending it, we will, in the following remarks, explain these principles in as simple a manner as possible, and institute a comparison between the respective merits of the single-cylinder expansive condensing engine and the compound engine:

The compound engine is a high and low-pressure condensing engine, having two ordinary steam cylinders, the smaller or high-pressure cylinder communicating direct with the boiler, the larger or low-pressure condensing cylinder direct with the condenser, and both with each other. The steam is admitted freely from the boiler into the high-pressure cylinder until the piston has been moved through a certain distance where the valve is so regulated that the communication with the boiler is entirely shut off, and the remainder of the space to be passed through by the piston is performed by the expansion of the steam now shut up in the cylinder, and which, after doing its work in this cylinder, passes on to the condensing cylinder, where it does an equal or proportionate quantity of work, and then passes into the condenser.

It has been found from modern practice that when the length of stroke of both cylinders is the same, it is necessary that the condensing cylinder be about three times greater in area than the high-pressure one, and this proportion is best suited when the steam employed is from 45 to 50 lbs pressure above the atmosphere, and cutting off the steam after being admitted during $\frac{1}{3}$ of the stroke in the high-pressure cylinder. When the steam to be employed is of a less pressure, but the point of cut-off the same, then the relative proportions of the cylinders must be nearer to each other, and the reverse when steam of a greater pressure is to be used.

To get the maximum of economy out of any class of expansive condensing engine, the pressure of steam and point of cut-off must be so regulated that the steam passes into the condenser at the end of the stroke at a pressure not exceeding 5 lbs. above a perfect vacuum, and with steam at 45 lbs. pressure above the atmosphere, which is equal to 60 lbs. pressure above a perfect vacuum (the pressure of the atmosphere being considered as equal to 15 lbs. on the square inch), and a terminal pressure of 5 lbs., we get 12 expansions, because the pressure at the end of the stroke is 12 times less than what it was at the point off cut-off, and is expressed by the formula—

$$\frac{P}{t} = R.$$

Where $P =$ pressure at point of cut-off, $t =$ terminal pressure, and $R =$ ratio or number of expansions, and as the pressure of steam, accoeding to Marriotte's law, varies inversely as the space it occupies, the steam will now fill 12 times the space it originally occupied at a pressure equal to $\frac{1}{12}$th of the original pressure, that is, supposing there had been no loss of heat during the process of expansion, and this we must suppose to simplify this inquiry.

On reference to the annexed table of average pressures, it will be seen that steam admitted at 60 lbs. pressure, and cut-off at $\frac{1}{12}$th part of the stroke, exerts an average pressure = 17.32 lbs. per sq. in. on the piston throughout the whole stroke, and, although this is 3½ times less work than would have been done had the steam been used at the full pressure of 60 lbs. throughout the whole length of the stroke, still only a 12th part of the cylinder's contents had been filled from the boiler, and the power required is thus got by working the steam expansively, at a saving equal to about 3½ to 1. (See page 148.)

As the point of cut-off may be different from any of those shown in the table, it is as well that the student should be in possession of a simple formula for ascertaining the average pressure for himself at any time, and the following is given to find out the mean pressure during a stroke in lbs. per sq. in. Let—

L = Whole length of stroke in inches.
l = Distance travelled by piston before the steam is cut off, in inches.
R = Ratio or number of expansions $= \frac{L}{l}$.
H = Hyperbolic logarithm of R.
P = Initial pressure of steam in lbs. per sq. in
p = Mean pressure during the stroke in lbs. per square inch.

Then, $p = P\frac{1 + H}{R}$.

A table of hyperbolic logarithms is also annexed so that H may be found without any difficulty.

TABLE OF HYPERBOLIC LOGARITHMS.

The Hyperbolic Logarithm of a number is found by multiplying the common Logarithm of the number by 2.30259.

No.	Logarithm.
1–1	.0953102
1–2	.1823215
1–3	.2623642
1–4	3364722
1–5	.4054652
1–6	.4700036
1–7	.5306282
1–8	.5877866
1–9	.6418538
2–0	.6931472
2–1	.7419373
2–2	.7884573
2–3	.8329090
2–4	,8754686
2–5	.9162907
2–6	.9555113
2–7	.9932518
2–8	1.0296913
2–9	1.0647107
3–0	1.0986124
3–1	1.1314021
3–2	1.1631508
3–3	1.1939224
3–4	1.2237754
3–5	1.2527629
3–6	1.2809338
3–7	1.3083328
3–8	1.3350010
3–9	1.3609765
4–0	1.3862943
4–1	1.4109869
4–2	1.4350845
4–3	1 4586149
4–4	1.4816045
4–5	1 5040773
4–6	1.5260563
4–7	1.5475625
4–8	1 5686159
4–9	1.5892352
5-0	1.6094379
5–1	1.6292405
5–2	1.6486586
5–3	1 6677068
5–4	1.6863989
5–5	1.7047481
5–6	1.7227665
5–7	1.7404661
5–8	1.7578579
5–9	1 7749523
6–0	1.7917595
6–1	1.8082887
6–2	1.8245493
6–3	1 8405496
6–4	1.8562979
6–5	1.8718021
6–6	1.8870697
6–7	1.9021075
6–8	1.9169226
6–9	1.9315214
7–0	1.9459100
7–1	1.9600947
7–2	1 9740810
7–3	1.9878743
7–4	2.0014800
7–5	2.0149030
7–6	2.0281482
7–7	2.0412203
7–8	2.0541237
7-9	2 0668627
8–0	2.0794414

No.	Logarithm.
8-1	2.0918640
8-2	2 1041341
8-3	2 1162555
8-4	2 1282317
8-5	2.1400661
8-6	2.1517622
8-7	2.1633230
8-8	2 1747517
8-9	2.1860512
9-0	2.1972245
9-1	2.2082744
9-2	2.2192034
9-3	2.2300144
9-4	2.2407096
9-5	2.2512907
9-6	2.2617631
9-7	2.2721258
9-8	2 2823823
9-9	2.2925347
10-0	2 3025851
11-0	2.3978953
12-0	2.4849065
13-0	2.5649494
14-0	2 6390572
15-0	2.7080502
16-0	2.7726067
17-0	2 8332341
18-0	2.8903847
19-0	2 9444497
20-0	2.9957322
21-0	3.0445437
22-0	3 0910562
23-0	3.1354964
24-0	3.1780715
25-0	3.2188757
26-0	3 2581099
27-0	3.2958495
28-0	3.3322306
29-0	3 3672992
30-0	3.4011974

In order to arrive at the merits and capabilities of the compound engine, let us first see what are the results got from a single-cylinder condensing engine of given dimensions and cutting off the steam to work with a certain number of expansions. Let—

$D =$ Diameter of cylinder in inches,
$L =$ Length of stroke in feet,
$N =$ Number of revolutions of crank per minute,
$p =$ Mean or average pressure on piston,

then, for arriving at the horse power we use the following formula :—

$$\frac{D^2 \times .7854 \times 2\,L \times N \times p}{33.000} = \text{horse-power.}$$

But as $D^2 \times .7854 =$ area of piston, and $2\,L \times N =$ speed of piston in feet per minute, we will make $D^2 \times .7854 = A$, and $2\,L \times N = S$, the formula then becomes

$$\frac{A \times S \times p}{33.000} = \text{H. P.}$$

and supposing the cylinder to be 24 in. diameter, length of stroke=4 ft.; number of revolutions per minute=50; pressure of steam at beginning of stroke=60 lbs. (all pressures here mentioned are above a perfect vacuum), point of cut-off, $= \frac{1}{12}$th part of the stroke, or, after the piston has travelled 4 in., so that—

$D = 24$ inches.
$2\,L = 8$ feet.
$N = 50$ revolutions.
$P = 60$ lbs.
$p = P\,\dfrac{1 \times H}{R} = 17.32$, we get—

$$\frac{452\ 4 \times 400 \times 17\ 32}{33.000} = 95 \text{ horse-power;}$$

To distribute this power equally over the working parts of a compound engine, it is desirable that both cylinders be so proportioned that they will each give out nearly the same power, and that the thrust caused by the entrance of the steam at the beginning of each stroke be the same in both cylinders.

To attain this with an accuracy sufficient for all practical purposes, it is necessary that the condensing cylinder be larger than the high-pressure cylinder in area, by the ratio of expansion that takes place in the high-pressure cylinder; that is to say, if

$a =$ area of piston in high-pressure cylinder,
$r =$ ratio of expansion in high-pressure cylinder,
$A =$ area of piston in condensing cylinder, then

$$A = a\,r.$$

So that if $P =$ initial pressure in small cylinder, and $P' =$ initial pressure in large cylinder, the area of large piston, multiplied by P', will be equal to the area of small piston multiplied by P, then $P'\,A = P\,a$.

But as the ratio of expansion is the same in both cylinders, and the whole ratio of expansion equal to the initial pressure in small cylinder, divided by the terminal pressure in large cylinder, we get $\sqrt{\dfrac{P}{t}} =$ ratio of expansion in each cylinder, and as we have already taken $P = 60$ lbs., and $t = 5$ lbs., we have $\sqrt{\dfrac{60}{5}} = 3.46 =$ differences of area of the two pistons, and also ratio of expansion in each cylinder, and consequently $= r$.

From the nature of the compound engine, the area opened up for the steam by the movement of the large piston is at all times decreased by a proportionate part $= \dfrac{A}{a\,r} = 1$, by the advancing area of small piston, so that the space actually occupied by the expanding steam is $= A - 1$, and from this we get the formula for ascertaining the av-

AVERAGE PRESSURE UPON PISTON DURING ONE STROKE.

For any Rate of Expansion.

Average Pressure in Lbs. upon the Piston.

Steam cut off at	Pressure in Lbs. at Commencement of Stroke—																			
	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	110	120	130	140	150
1/3	21	24½	28	31½	35	38½	42	45½	49	52½	56	59½	63	66½	70	77½	84	91	98	105
2/3	28¼	32¾	37½	42	46¾	51½	56¼	61	65½	70¼	75	79½	84½	89	93¾	103	111½	121¾	131	140½
1/4	17¾	20¾	23¾	26¾	29¾	32¾	35¾	38¾	41¾	44¾	47¾	50¾	53¾	56¾	59¾	65½	71½	77½	83½	89½
1/2	25¼	29½	33¾	38	42¼	46½	50¾	55	59¼	63½	67¾	72	76¼	80½	84¾	93¼	101½	110	118½	127
3/4	28¾	33½	38½	43¼	48¼	53	57¾	62½	67½	72¼	77¼	82	87	91¾	96½	106¼	115¾	125½	135¼	144¾
1/5	15½	18¼	20¾	23½	26	28½	31¼	34	36½	39	41¾	44¼	47	49½	52¼	57¼	62½	67¾	73	78½
2/5	23	26¾	30½	34½	38¼	42	46	49¾	53½	57½	61¼	65	69	72¾	76½	84¼	91¾	99½	107¼	115
3/5	27	31½	36¼	40¾	45¼	49¾	54¼	58¾	63¼	67¾	72½	77	81½	86	90½	99½	108¾	117¾	126¾	135
4/5	29¼	34¼	39	44	49	53¾	58½	63½	68½	73¾	78¼	83	88	92¾	97¾	107½	117½	127¼	136¾	146¾
1/6	14	16¼	18½	20¾	23¼	25½	27¾	30¼	32½	34¾	37¼	39½	41¾	44¼	46½	51¼	55¾	60½	65	69¾
5/6	29½	34½	39½	44¼	49¼	54	59	64	69	73¾	78¾	83¾	88¾	93½	98½	108¼	118¼	128	137¾	147
1/7	12½	14¾	16¾	18¾	21	23¼	25¼	27¼	29½	31½	33½	35¾	37¾	40	42	46¼	50½	54¾	58¾	63
2/7	19¼	22½	25¾	28¾	32	35¼	38½	41¾	45	48¼	51½	54½	57¾	61	64¼	70¾	77¼	83½	90	96½
3/7	23¾	27¾	31½	35½	39½	43½	47½	51½	55¼	59¼	63¼	67¼	71¼	75¼	79	87	94¼	102¼	110¾	118¾
4/7	26¾	31¼	35½	40	44½	49	53½	57¾	62½	66¾	71¼	75¾	80	84½	89	98	106¾	115¾	124¾	133½
5/7	28½	33½	38¼	42¾	47¾	52½	57¼	62	66¾	71½	76¼	81	85¾	90¾	95½	105	114¼	124	133½	143¼
6/7	29½	34½	39½	44½	49½	54¼	59¼	63¾	69¼	74¼	79	84	89	93¾	98¾	108¾	118¾	128½	138½	148¼
1/8	11½	13½	15¼	17¼	19¼	21¼	23	25	27	28¾	30¾	32¾	34½	36½	38½	42¾	46¼	50	54½	57¾
3/8	22¼	26	29¾	33½	37	40¾	44½	48¼	52	55¾	59½	63	66¾	70½	74¼	81¾	89	96½	104	111½
5/8	27½	32	36¾	41¼	45½	50½	55¼	59¾	64¼	68¾	73½	78	82½	87¼	91¾	101	110¼	119½	128½	137¾
7/8	29¾	34¾	39½	44½	49½	54½	59½	64½	69¼	74¼	79¼	84¼	89¼	94¼	99	109	119	128¾	138¾	148¾
1/9	10½	12¼	14¼	15¾	17¾	19½	21¼	23	24¾	26½	28¼	30¼	31¾	33¾	35½	39	42½	46	49½	53¼
2/9	16½	19¼	22¼	25	27¾	30½	33¼	36	38¾	41¾	44½	47¼	50	52¾	55½	61	66¾	72¼	77¾	83
4/9	24	28	32	36	40¼	44¼	48¼	52¼	56¼	60¼	64¼	68¼	72¼	76¼	80½	88½	96½	104½	112½	120½
5/9	26¼	30¾	35¼	39½	44	48½	52¾	56½	61¾	66	70½	74¾	79¼	83¾	88	97	105¾	114½	123¼	132¼
7/9	29	34	38¾	43¾	48½	53½	58¼	63¼	68	72¾	77¾	82¾	87½	92¼	97¼	107	116¾	126½	136¼	145
8/9	29¾	34¾	39¾	44½	49½	54½	59½	64½	69½	74½	79¼	84¼	89¼	94¼	99¼	109¼	119¼	129	139	149
1/11	9¼	10¾	12¼	13¾	15¼	16¾	18½	20	21½	23	24½	26¼	27¾	29¼	30¾	33¾	37	40	43¼	46¼
2/11	14¾	17¼	19½	22	24½	27	29½	31¾	34¼	36¾	39¼	41¾	44¼	46¾	49	54	59	63¾	68¾	73¾
3/11	18¾	21¾	25	28	31¼	34¼	37½	40¾	43¾	47	50	53¼	56¼	59½	62½	68¾	75¼	81½	87¾	94
4/11	21¾	25½	29¼	32¾	36½	40¼	43¾	47½	51	54¾	58½	62	65¾	69½	73	80¼	87¾	95	102¼	109½
5/11	24¼	28¼	32½	36½	40½	44½	48¾	52¾	56¾	60¾	65	69	73	77	81¼	89¼	97½	105½	113¾	121¾
6/11	26¼	30½	35	39¼	43¾	48	52½	56¾	61¼	65½	70	74¼	78¾	83	87½	96¼	105	113¾	122½	131
7/11	27½	32¼	36¾	41½	46	50¾	55¼	60	64½	69¼	73¾	78½	83	87¾	92¼	101½	110¾	120	129¼	138½
8/11	28¾	33½	38¼	43	47¾	52¾	57½	62¼	67	71¾	76¾	81½	86¼	91	95¾	105¼	115	124½	134¼	143½
9/11	29¼	34¼	39¼	44	49	54	58¾	63¾	68¾	73½	78½	83½	88¼	93¼	98¼	108	117¾	127½	137½	147¼
1/12	8½	10	11½	13	14½	15¾	17¼	18¾	20¼	21¾	23¼	24½	26	27½	29	31¾	34¾	37¾	40½	43½

erage pressure in the condensing cylinder of a compound engine.

$$p' = P' \frac{H}{R-1.}$$

A table showing the relative areas of the two cylinders of a compound engine, with the average pressure in each cylinder, etc.:

P	R	P′	H	S	p′	p
30	2.449	12.25	.896	23.23	7.52	15.71
35	2.645	13.22	972	26.10	7 83	18.27
40	2 828	14.14	1 040	28.85	8 04	20 81
45	3 000	15.00	1.098	31.47	8.22	23 25
50	3.162	15.86	1.150	34 00	8.40	25.60
55	3 316	16.58	1.197	36.44	8.58	27.86
60	3.464	17.32	1 242	38.83	8.74	30.09
65	3 605	18.02	1.281	41.13	8.85	32.28
70	3.741	18.70	1.319	43.39	9 08	34.31
75	3.872	19.36	1.353	45 57	9.11	36.46
80	4.000	20.00	1 386	47.72	9.24	38 48
85	4 123	20.61	1.415	49 78	9.34	40.44
90	4 242	21 21	1.444	51 85	9 44	42.41
95	4.358	21.80	1.470	53.84	9 56	44.28
100	4 472	22 36	1 497	55.84	9.64	46.20
105	4.582	22.91	1.521	57.77	9 73	48.04
110	4 690	23 45	1.545	59.69	9.82	49.87
115	4 795	23.98	1.567	61.57	9.89	51.68
120	4.898	24.45	1.589	63.43	9.96	53.47
125	5.000	25.00	1.609	65.32	10.05	55.27
130	5.099	25.50	1.629	67.02	10.13	56.89
135	5.196	26 00	1.647	68.77	10.21	58.66
140	5.291	26.46	1 665	70.51	10.26	60.25
145	5 385	26 93	1 683	72.25	10 32	61 93
150	5 477	27.38	1.700	73.95	10.38	63 57
155	5.567	27.84	1.716	75.67	10.46	65.21
160	5 656	28.32	1.732	77.28	10.52	66.76
165	5.744	28.72	1.748	78.93	10 58	68 35
170	5 830	29.15	1.763	80.56	10 64	69 92
175	5 916	29.58	1.777	82.14	10 70	71.44
180	6 000	30 00	1.791	83.73	10.75	72.98
185	6.082	30.41	1 805	85 32	10.80	74.52
190	6.164	30.82	1 818	86 86	10.85	76.91

The accompanying table has been drawn out for easy reference in conformity with this rule. The first column = P = the initial pressure of the steam above a perfect vacuum on entering the small cylinder; the second $= R = \sqrt{\frac{P}{t}}$ shows the relative areas of the two cylinders, and also the number of expansions in high-pressure cylinder; the third column, = P = the terminal pressure in high-pressure cylinder, gives the pressure at beginning of stroke in condensing cylinder; the fourth column, = H, contains the hyperbolic logarithms of R; the fifth, = S, gives the average pressure during a stroke in a single cylinder, for the different values of R and $= P \frac{1+H}{R}$; the sixth column, = p′, gives the average pressure during a stroke in the condensing cylinder of a compound engine, and $= P' \frac{H}{R-1}$ and the last column, p, gives the average pressure during a stroke in the high-pressure cylinder $P = \frac{1+H}{R} - P' \frac{H}{R-1}$.

Now, as the power to be given out by both cylinders is to be the same, the power that is required to be given out by $A = \frac{95}{2} = 47.5$ horse-power, and as $\sqrt{\frac{60}{5}} = 3.464$, $t \times 3.464 = 17.32 = P'$, and from the above formula we get $p' = 17.32 \frac{H}{R-1} =$ 8.74 lbs. average pressure per square inch on piston So that we can now get what area of piston is required to give out this power by

$$\frac{47.5 \times 33.000}{400 \times 8.74} = 450 = 24'' \text{ diameter.}$$

and as the area of the two pistons are to each other as 1 to 3.464, we get the area of small piston = 130 sq. in. = 13″ diameter.

Table of the pressure, temperature, volume, and mechanical effect of steam.

Total pressure in lbs. per square inch.	Corresponding temperature.	Volume of steam compared with volume of water.	Mechanical effect of a cubic inch of water evaporated, in lbs. raised 1 ft. high.
1......	102 9	20868	1739
2......	126.1	10874	1812
3......	141.0	7437	1859
4.... .	152 3	5685	1895
5......	161 4	4617	1924
6......	169.2	3897	1948
7	175.9	3376	1969
8......	182.0	2983	1989
9	187.4	2674	2006
10......	192.4	2426	2022
11......	197.0	2221	2036
12......	201.3	2050	2050
13......	205.3	1904	2063
14......	209.1	1778	2074
15......	212.8	1669	2086
16 . .	216.3	1573	2097
17......	219.6	1488	2107
18	222 7	1411	2117
19......	225.6	1343	2126
20	228 5	1281	2135
21......	231 2	1225	2144
22	233.8	1174	2152
23	236.3	1127	2160
24......	238 7	1084	2168
25	241.0	1044	2175
26.....	243.3	1007	2182
27......	245 5	973	2189
28......	247 6	941	2196
29	249.6	911	2202
30......	251.6	883	2209

Total pressure in lbs. per square inch.	Corresponding temperature.	Volume of steam compared with volume of water.	Mechanical effect of a cubic inch of water evaporated, in lbs. raised 1 ft. high.
31	253.6	857	2215
32	255.5	833	2221
33	257.3	810	2226
34	259.1	788	2232
35	260.9	767	2238
36	262.6	748	2243
37	264.3	729	2248
38	365.9	712	2253
39	367.5	695	2259
40	269.1	679	2264
41	270.6	664	2268
42	272.1	649	2273
43	273.6	635	2278
44	275.0	622	2282
45	276.4	610	2287
46	277.8	598	2291
47	279.2	586	2296
48	280.5	575	2300
49	281.9	564	2304
50	283.2	554	2308
51	284.4	544	2312
52	285.7	534	2316
53	286.9	525	2320
54	288.1	516	2324
55	289.3	508	2327
56	290.5	500	2331
57	291.7	492	2335
58	292.9	484	2339
59	294.2	477	2343
60	295.6	470	2347
61	296.9	463	2351
62	298.1	456	2355
63	299.2	449	2359
64	300.3	443	2362
65	301.3	437	2365
66	302.4	431	2369
67	303.4	425	2372
68	304.4	419	2675
69	305.4	414	2378
70	306.4	408	2382
71	307.4	403	2385
72	308.4	398	2388
73	309.3	393	2391
74	310.3	388	2394
75	311.2	383	2397
76	312.2	379	2400
77	313.1	374	2403
78	314.0	370	2405
79	314.9	366	2408
80	315.8	362	2411
81	316.7	358	2414
82	317.6	354	2417
83	318.4	350	2419
84	319.3	346	2422
85	320.1	342	2425
86	321.0	339	2427
87	321.8	335	2430
88	322.6	332	2432
89	323.5	328	2435
90	324.3	325	2438
91	325.1	322	2440
92	325.9	319	2443
93	326.7	316	2445
94	327.5	313	2448
95	328.2	310	2450
96	329.0	304	2453
97	329.8	304	2455
98	330.5	301	2457
99	331.3	298	2460
100	332.0	295	2462
110	339.2	271	2486
120	345.8	251	2507
130	352.1	233	2527
140	357.9	218	2545
150	363.4	205	2561
160	368.7	193	2577
170	373.6	183	2593
180	378.4	174	2608

From this we can see that for a compound engine to exert the same power as a single-cylinder condensing engine with the same number of expansions in both cases, the condensing cylinder of the compound engine requires to be equal in diameter to the single condensing cylinder; and from this being the case, it is quite reasonable to say, that if the power exerted can be got from one cylinder with the steam expanded a certain number of times, it would be unwise to add to the expense of the engine by expanding the same number of times in two cylinders instead of one. But as the source of the power obtained is the heat passed into the cylinder from the boiler, and as the economical working of the engine depends on the greatest quantity of this heat that can be converted into power, it is herein where the compound engine has the advantage over any other class of engine, and we will compare the single and the compound engine from this point of view.

The steam enters the single-cylinder engine at a pressure=60 lbs. per sq. in., the temperature of which, on reference to the annexed table, will be found to be equal to 295.6 deg. After doing its work it terminates with a pressure = 5 lbs.=161.4 deg. in temperature, and consequently has cooled down the cylinder to the same temperature, so that the fresh steam on entering to perform the next stroke can only be effective at a temperature corresponding to its pressure, and it has to part with its heat until it brings the cylinder up to its own temperature, and has consequently to be supplied with new steam from the boiler to do its work.

Now the pressure at the beginning of the stroke of the high-pressure cylinder of the compound engine is the same=60 lbs. per sq. in.; but owing to the fewer number of expansions carried out in this one cylinder, it terminates this stroke with a pressure=17.32 lbs. per sq. in., the temperature of which will be found on reference to be 220 deg., being a difference of only 76 deg. instead of 135 deg., or just about one-half. A great part of this waste of the heat that is passed into the cylinder can be prevented by having a space round about the cylinder, and at both ends, filled with steam at the boiler pressure; but this steam jacket, as it is called, is much more effective in the compound engine than in the single cylinder engine, for this reason: It has been found from experiment that the rapidity with which two volumes of steam of different temperatures seek to equalize themselves is as the square of their difference in temperature, that is to say—that if you mix steam of 200 deg. with steam of 100 deg., and steam of 400 deg. with steam of 100 deg., the difference of temperatures of the former being as 2 to 1, and of the latter as 4 to 1, and as $2^2=4$, and $4^2=16$; the latter temperatures will seek to equalize themselves four times quicker than the former, and, as the variation of temperature is much greater in the single cylinder than in either of the cylinders of a compound engine, the heat from the steam jacket must pass through the metal with great rapidity to replace that wasted by condensation, and this it cannot do so effectively as when the temperatures are not so widely varied; and this is one of the great advantages possessed by the compound or double-cylinder engine. Another feature in which the compound engine bears favorable comparison with the single-cylinder engine is in the difference of the thrust caused by the entrance of the steam at the beginning of each stroke, and consequently on the amount of pressure or friction thrown on the crank pin and crank shaft journals, compared with the power to be exerted. If we multiply the area of piston in single cylinder by the initial pressure, we get $452\times60=27{,}120$ lbs. total pressure, or equal to a blow of fully 12 tons at the beginning of the stroke. If, in like manner, we multiply the areas of both pistons of the compound engine by their respective initial pressures we get $131\times60=7{,}860$ and $452\times17.32=7{,}828$, which being added together, gives a total pressure at beginning of stroke when both pistons are moving simultaneously$=15{,}688$ lbs.=about 7 tons or little more than one-half of that in the single cylinder, and from this it can be easily seen that as a less shock is given to the working parts by about one-half, the dimensions of these parts can be made proportionately less, and a gentler, steaddier, but equally effective motion is imparted.

The compound engine, both for marine and stationary purposes, has had the position of its cylinders and the combinations of its parts arranged in many different ways, in some cases to suit the space available for its erection, and in others, according to the different ideas of the different manufacturers; but the principle being the same in all cases, an equal economy should be got if care is taken in so proportioning the passages for the steam that no undue obstruction is caused, and that proper and efficient means are employed to prevent any waste of heat as far as possible.

The principle of the compound engine was known as early as 1781, when a patent was taken out by Jonathan Hornblower for "Employing the steam after it has acted on the first vessel to operate a second time in the other by permitting it to expand itself." But Hornblower was never able to carry out the principle to be of much practical use, owing to Watt's patents being in existence at the time.

The earliest compound engine in which the principle was practically carried out was patented in 1804 by Arthur Woolf, and his style of engine has been in use almost ever since that date in France and the Continent generally, and is still constructed by many engineers in this country, and is known as "Woolf's Engine," and employed for stationary purposes only. Both the cylinders are placed together at one end of the walking beam, the condensing cylinder being at the outer end, and the high-pressure cylinder close up to it with a proportionately less stroke. This arrangement is perfectly capable of carrying out the principle equal to any other. But the great pressure it exerts on the main centre of the walking beam, owing to all the power requiring to pass from the one end of the beam to the other, has caused it to be less extensively used than otherwise might have been the case; but more especially since 1845, when a patent was taken out by Wm. McNaught, wherein this great pressure is removed from the main centre by having the condensing cylinder only at the outer end of beam, and the high-pressure cylinder between the main centre and the crank, thus having the power equal on both sides of the main centre, and the pressure consequently merely nominal at that part. This arrangement is by far the best when the engine has to be of the walking-beam class.

Another good arrangement is carried out in horizontal engines, with both cylinders lying side by side (generally cast together in one piece), and secured to a single sole plate; both piston rods are attached to one crosshead, so that one connecting rod conveys the whole power to the crank, nothing being in duplicate but the cylinders.

In the compound engine at present so largely employed in the British Navy, the cylinders, outwardly, are the same diameter, but the high-pressure cylinder, as previously mentioned, is generally made about $\frac{1}{3}$ less in area than the condensing cylinder. The space round the actual high-pressure cylinder being used to receive its exhaust steam until the valve of condensing cylinder opens to admit it, as the pistons do not move simultaneously, owing to the cranks being at right angles to each other.

It has been explained in the first part of this work that the nominal horse power of an engine is ascertained by assuming the mean pressure on the piston to be equal to 7 lbs. on the square inch, and the speed of piston equal to 220 ft. per minute. But as both the working pressure and speed of piston have been greatly increased since the above rule was first adopted, it fails to convey any adequate idea of the actual capabilities of the engine. Still, in all negotiations connected with the purchase of a steam engine, it is, as a rule, the nominal horse power alone that is referred to, although it is understood that with a pressure, say of about 60 lbs., and a piston speed of about 400 ft. per minute, fully six times the nominal power is got from a condensing engine.

As the term "Nominal Horse-Power" is only used when speaking of the steam engine as a marketable commodity, a particular size of cylinder may be called a certain nominal power by one maker, and a different nominal power by another, and unfair competition often takes place by two manufacturers offering for sale say an 80 horse-power condensing engine, one of whom means to give a cylinder 50 in. diameter, whilst the other calls a 40 in. cylinder the same nominal power. The rules now generally adopted in this country to determine the nominal power of the different kinds of steam engines are as follows:—

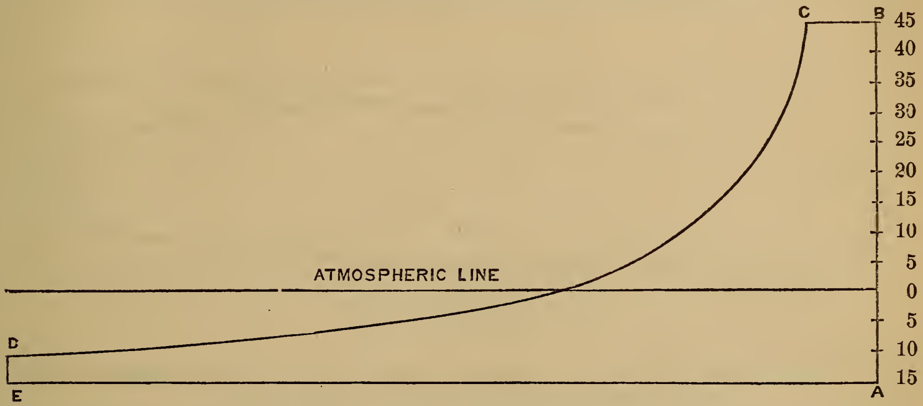
Rule to find the nominal horse-power of a high-pressure non-condensing steam engine: Square the diameter of cylinder in inches, and divide by 12, that is to say, a non-condensing engine with a cylinder=30 in. diameter, is called a 75 horse-power engine nominal, although it is capable of giving out at least three times the power when a pressure of say 60 lbs. is employed, and piston speed=400 ft. per minute.

Rule to find the nominal horse-power of a single cylinder condensing engine: Square the diameter of cylinder in inches, and divide by 24, that is to say, that a condensing steam engine with a cylinder=30 in. diameter, is called a 37½ horse-power engine nominal, but is capable of working to at least six times its nominal power with 60 lbs. pressure and speed of piston=400 ft. per minute.

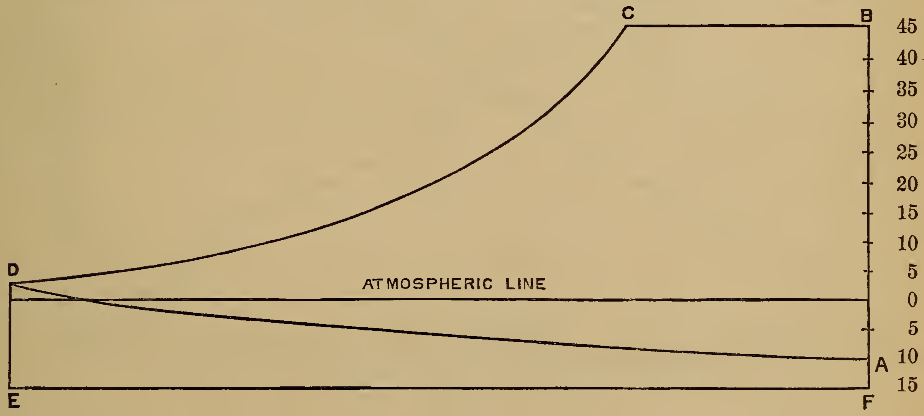
The rule now generally adopted by marine engineers for the nominal power of a compound engine is: Add the square of the diameter of each cylinder in inches together, and divide the sum by 30, that is with a compound engine whose condensing cylinder is 30 in. diameter, and high-pressure cylinder 17 in. diameter, is called a 40 horse-power compound engine nominal, and is also capable of working to at least six times that power with 60 lbs. pressure and speed of piston=400 ft. per minute.

Some diagrams are herewith given, the first two of which are theoretical, and the shape that would actually be got was there no loss of heat during the stroke from condensation or other causes. In the theoretical diagram, showing the expansion curve when the steam is expanded 12 times in a single cylinder condensing engine, A B represents the total initial pressure of 60 lbs., B C the constant supply of steam from the boiler at that pressure, C the point where the steam is entirely shut off$=\frac{1}{12}$th part of the stroke, C D the expansion curve formed by the decreasing pressure of the steam in the ratio that the space it occupies is increased by the advance of the piston, D E represents the terminal pressure, and E A the line of perfect vacuum. In the compound theoretical diagram, C D is the expansion curve formed from the high-pressure cylinder, and D A the expansion curve formed from the condensing cylinder, the line F B representing the initial pressure of 60 lbs., D E the terminal pressure in high-pressure cylinder, and initial pressure in low-pressure cylinder, and equal to 17.32 lbs., and F A the terminal pressure in low-pressure cylinder, and equal to 5 lbs.

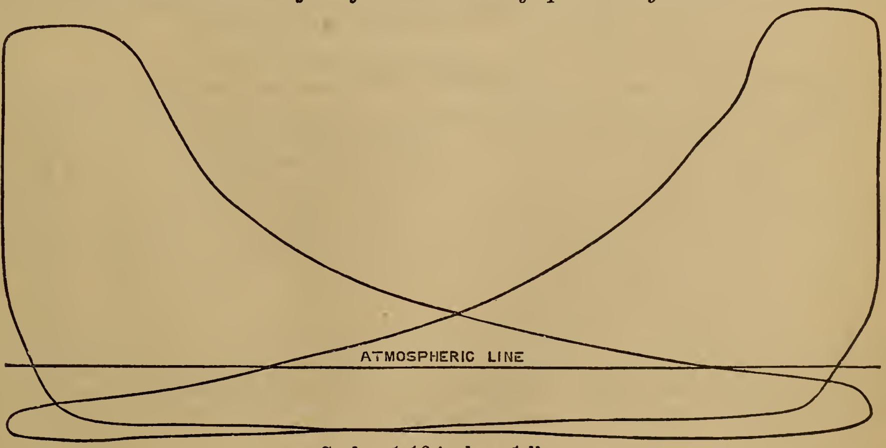
A Theoretical Diagram showing the Expansion Curve in a Single Cylinder Condensing Engine, with Steam at 60 *lbs. pressure above a perfect vacuum, expanded* 12 *times.*



Theoretical Diagrams showing the Expansive Curve in both Cylinders of a Compound Engine, with Steam at 60 *lbs. pressure above a perfect vacuum. Total number of expansions* = 12.

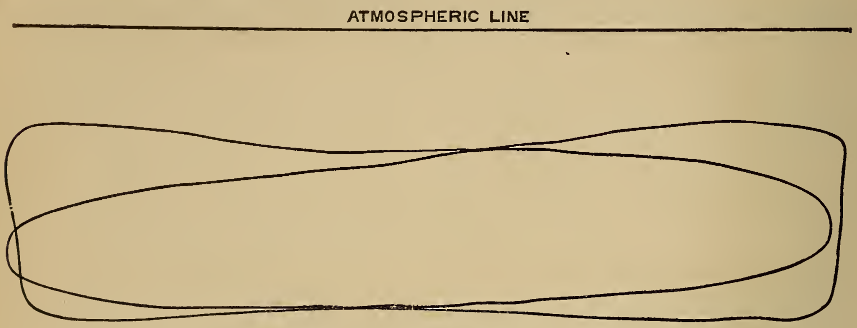


HIGH PRESSURE.—*Diagrams taken from a Compound Engine with Steam cut-off after the Piston has travelled one-eighth of the stroke in high-pressure Cylinder.*



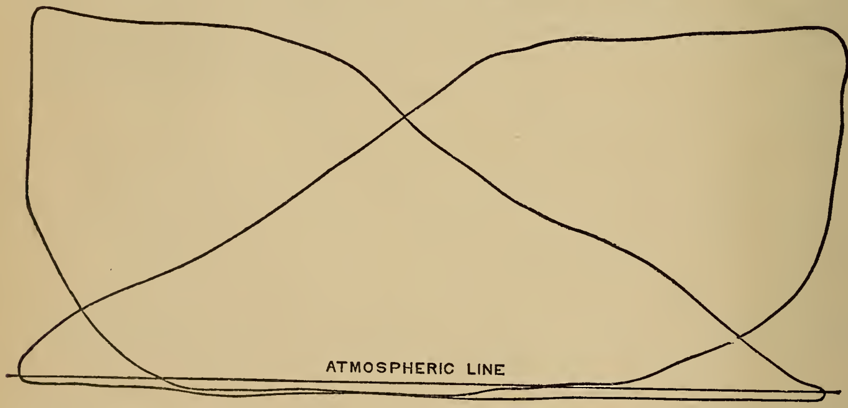
Scale—1-16 inch = 1 lb.

Low Pressure.—*Diagrams taken from a Compound Engine with Steam cut-off after the Piston has travelled one-eighth of the stroke in high-pressure Cylinder.*



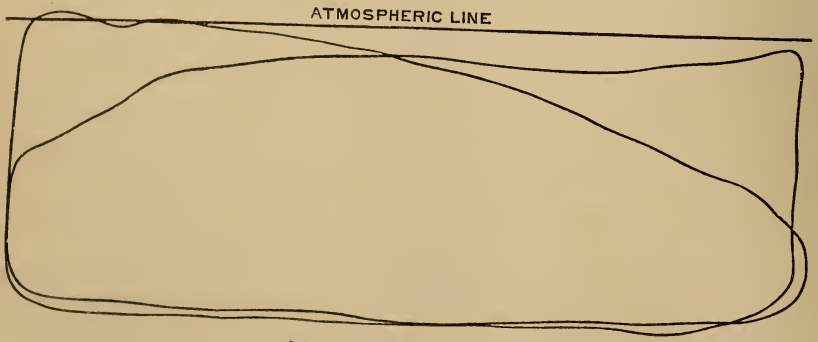
Scale - 1-8th inch = 1 lb.

High Pressure.—*Diagrams from the Compound Engine of the S. S. "Dunluce Castle"—Steam cut-off at one-half the stroke in high-pressure Cylinder.*



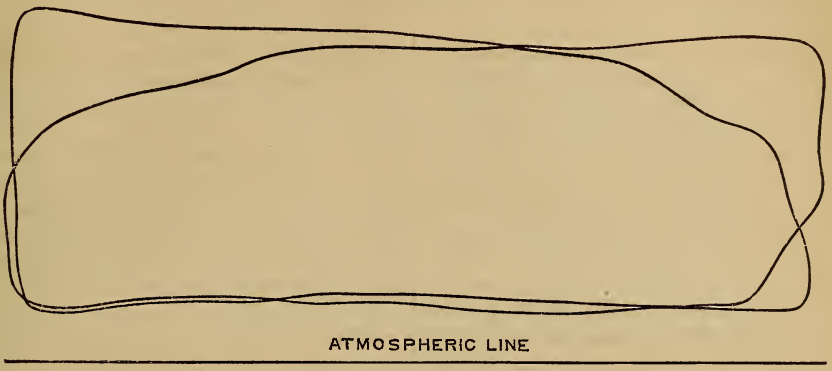
Scale—1-24th inch = 1 lb.

Low Pressure—*Diagrams from the Compound Engine of the S. S. "Dunluce Castle"—Steam cut-off at one-half the stroke in high-pressure Cylinder.*



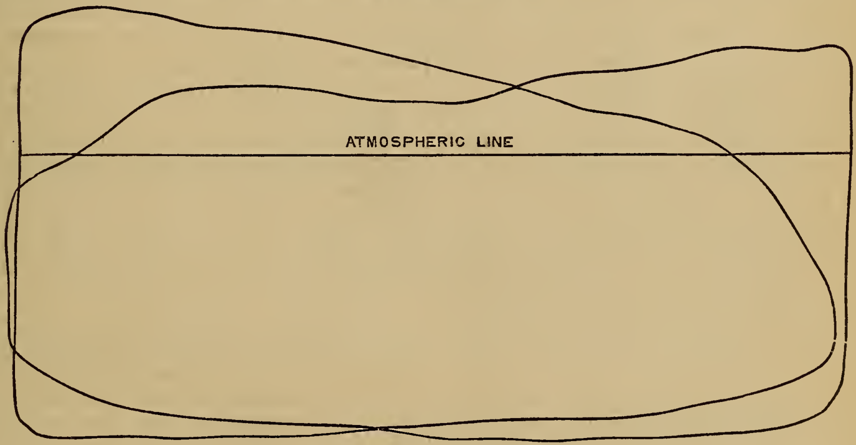
Scale—1-8th inch = 1 lb.

HIGH PRESSURE.—*Diagrams from the Compound Engine of the S. S. "Dunluce Castle, with the Link full out.*



Scale—1-24th inch = 1 lb.

LOW PRESSURE.—*Diagrams from the Compound Engine of the S. S. "Dunluce Castle," with the Link full out.*



Scale—1-8th inch = 1 lb.

ON STEAM-BOILER EXPLOSIONS.*

The subject which I propose to bring before you this evening, is chiefly interesting from its exemplifying the relation that subsists between the philosophy and the application of science. It often happens that theory follows in the wake of discovery, and that experience grows familiar with important details of practice before the abstract principle involved is sought out and clearly recognized.

In what I shall advance to-night, a different sequence will be apparent, and we shall have an illustration of the value of a scientific application of common every-day facts, in the solution of problems of the utmost moment to human life.

I allude to the property which liquids possess, of assuming the form of a globe or spheroid, when thrown upon any substance which is at a high temperature. Of this

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* A paper read before the Royal Manchester Institution, by John Eddowes Bowman.

It is some years since this paper was first published. It is justly regarded as a valuable contribution to the literature of thermodynamics. As it has long been out of print, it is now reprinted as a proper supplement to our former article on the same subject.—ED.

property, a familiar instance is afforded by an experiment performed every day in our laundries. When it is required to know whether a smoothing iron is sufficiently hot for her purpose, the laundress, on taking it from the stove, applies extemporaneously a drop of moisture from her lips, and if this at once rolls off in the form of a globule, she knows by experience that the iron has reached a proper temperature; while if the drop of water bubbles and boils, however violently, it is condemned as not hot enough, and returned to the stove.

Once, then, in the flight of ages past, it was discovered that water, though it so readily boils when thrown upon a moderately hot iron, does not boil at all when in contact with metal considerably more heated.

This fact, like many others equally familiar, has been allowed to lie unexplained and uninterrogated during a long lapse of time; and it is only within the last few years that it has attracted any attention from the physical philosopher.

During my stay in Paris last winter, I had an opportunity of seeing, in the laboratory of Dumas, some experiments performed by M. Boutigny, of Evreux, who has devoted a great deal of time to the subject, and succeeded in bringing to light some most curious facts: so contrary indeed are some of his results to our preconceived ideas, that I confess I should hardly have believed them possible, if I had not witnessed them.

Some of these experiments I will now proceed to describe, showing one or two of the most remarkable by way of illustration; and before I conclude, I propose briefly noticing the important consequences of this property of water, in being the frequent cause of steam-boiler explosions.

It is generally stated in books, that a red or white heat is necessary in order to throw the water into this globular form. Far lower temperatures, however, are sufficient. This may be proved by throwing some water into a saucer of lead, a metal which melts long before it becomes luminous in the dark; the water shows no appearance of boiling, but rolls about like a little crystal ball for a considerable time. M. Boutigny, indeed, succeeded in forming a spheroid of water in a capsule floating on oil heated to not more than 340 deg., which is about 600 deg. below what is usually called "red heat."

Liquids more volatile than water become spheroidal at still lower temperatures. Alcohol, for instance, requires to be heated to 273 deg.; ether not higher than about 140 deg.; and it is found in general, that those liquids which require the highest temperature for boiling, require also the highest to make them assume the spheroidal figure.

Water and other liquids, when in the spheroidal state, slowly and gradually disappear, though no appearance of boiling is ever observed. This is of course owing to slow evaporation, which goes on from every part of its surface, thus enveloping it with a film of vapor.

Of the extreme slowness of the evaporation, some opinion may be formed from the fact, which has been proved by direct experiment, that a quantity of water which would, under ordinary circumstances, boil away at a temperature of 212 deg. in 1 min., will, if thrown into a vessel heated nearly to redness, require little less than an hour for its total dispersion.

The next point of our inquiry is one of extreme interest.

We have seen that when water is thrown upon a surface of red-hot platinum, it does not, as we might have expected, explode violently into steam, but, on the contrary, rolls calmly on its axis like a little world in space, and continues in the liquid state for a considerable length of time.

Let us, then, now endeavor to ascertain what is the temperature of the globule of water, and what relation it bears to that of the heated vessel, as well as to that of its own thin coating of vapor. And this I hope to prove by a simple experiment.

Let a large spheroid of water be formed in a tolerably thick crucible of platinum or silver, and the bulb of a small and delicate thermometer be carefully plunged into the middle of it, taking care not to allow it to come in contact with the heated metal. The temperature of the water thus ascertained is invariably 205 deg.

Perhaps one of the most curious facts which have been established in connection with this subject, is, that any variation in the temperature of the vessel containing a spheroid, does not affect the temperature of the spheroid itself. Thus it is found that a spheroid of water, when contained in a crucible heated considerably below redness, is just as hot as one contained in a crucible intensely heated to whiteness in the most powerful blast furnace!

From numerous experiments, indeed, with water, alcohol, ether, and many other liquids, the following law may be deduced: "That bodies in the spheroidal state remain constant at a temperature below that of boiling, however high the temperature of the containing vessel may be."

Pure alcohol, which, under ordinary circumstances, boils at a temperature of 173 deg., never rises, when in the spheroidal state, higher than about 170 deg.,; and ether, whose usual boiling point is about 100 deg., and which almost boils with the heat of the hand, cannot be induced, when thrown into a crucible heated to whiteness in a smith's forge, to rise above 95 deg.

The same remarkable results are obtained if, instead of pouring the liquids while cold into the red-hot vessels, they be absolutely boiling at the moment; strange, and almost incredible as it may appear, the instant they reach their fiery resting place, they absolutely become cooler, and, as it were, shaking off the trammels of all known laws of nature, cease to boil!

Liquids, then, when in that peculiar physical condition which I have called spheroidal, always remain at one definite temperature; and this temperature is invariably, in the case of every liquid, lower than that at which, under ordinary circumstances, that liquid boils. Let us inquire a little more narrowly into the consequences of this law.

Dr. Faraday, by a simple and ingenious contrivance, succeeded, some years ago, in condensing into the liquid state, several of the gases which had, up to that time, resisted all such attempts, and had consequently been considered permanent gases, such as the air we breathe. This was the case with carbonic acid, chlorine, ammonia, sulphurous acid, and a few others. So great is the elastic force of these liquefied gases, or in other words, so prone are they to boil, and to pass again into the gaseous form, that a very great pressure is necessary to prevent their doing so; and unless the tube or other vessel containing them were very strong, it would probably be burst with a most violent explosion. Now it will readily be understood how it happens that these condensed liquids, unlike water and most other fluids, do not require the application of artificial heat to make them boil, but, on the contrary, continue to boil, even when cooled very far below the usual temperature of the air. Let us then inquire whether any of these liquids, whose boiling points are far below that at which water freezes, be subject to the same law as water is subject to, when they are thrown into a vessel sufficiently hot to cause them to pass into the spheroidal state.

The gas which is most easily liquefied of those which I have alluded to, is sulphurous acid, which requires, at a temperature of 45 deg., a pressure equal to two atmospheres (or about 30 lbs. to the square inch of surface), to prevent it boiling. If this pressure be removed, violent ebullition takes place; and it has been found that even when cooled as low as 14 deg. of Fahrenheit's thermometer, or in other words, 18 deg. below the melting point of ice, it boils in precisely the same way as water boils when heated to 212 deg. Fourteen degrees, then, is the boiling point of sulphurous acid.

But we have found that when liquids, even while boiling, are thrown into a heated crucible, they become cooler, and remain constant at a temperature a few degrees below their boiling point. What then will be the effect of pouring into a red-hot crucible a few drops of liquid sulphurous acid?

The experiment which was selected for the purpose of furnishing an answer to this question, is perhaps one of the most striking and apparently paradoxical in the whole range of physical science. Liquid sulphurous acid is subject to the same remarkable law as water and other liquids, in being invariably, when in the spheroidal state, at a temperature lower than its boiling point, which is 14 deg. of Fahrenheit's thermometer; so that if a spheroid of sulphurous acid be formed, it remains constant at a temperature of about 12 deg., even though the crucible containing it be at a red or a white heat. If a little water contained in a small glass bulb, $\frac{1}{8}$ or $\frac{1}{10}$ in. in diameter, be immersed in the spheroid of acid, it is almost instantly frozen, thus affording incontestable evidence of the remarkably low temperature of the spheroid.

Most persons have seen the well-known lecture-table experiment of causing water and other liquids to boil in vacuo at temperatures considerably below their ordinary boiling points; a result depending upon the diminished pressure on their surface. When liquids in the spheroidal state, however, are placed under the receiver of the air pump, and the air removed, no sign of boiling is ever perceived. We may therefore suppose that the temperature of the spheroid in vacuo is lower than when exposed to the atmospheric pressure, as otherwise ebullition would inevitably take place; but I am not aware that the temperature has ever been examined with a thermometer under these circumstances, and it would be by no means easily done.

I shall probably scarcely be believed when I say that even liquid sulphurous acid does not, when contained in a red-hot vessel, and in the spheroidal state, boil in vacuo.

If a thermometer be held in the atmosphere of vapor which surrounds a spheroid of water, it will give a far different result from that ensuing from its immersion in the globe itself.

Instead of indicating, as before, the temperature of 205 deg., however hot the crucible may be, the degree at which it stands will now be found to depend entirely on the temperature of the latter. If it be heated to 400 deg., the thermometer will rise to that point; or if the crucible be raised to a red heat, a mercurial thermometer, graduated to 600 deg., is instantly burst, showing a temperature considerably higher.

We have proved experimentally, that when water is thrown into a red-hot crucible, it does not, as common sense would have foretold, begin to boil, but remains constant at the temperature of 205 deg. so long as it retains the spheroidal form, however high the temperature of the crucible which contains it may be; but that the vapor surrounding it is, on the contrary, always about the same temperature as the crucible.

This comparatively low temperature of liquids in the spheroidal state, is generally attributed to the coating of vapor round the spheroid, being incapable, as it is conceived, like all other gaseous bodies, of conducting heat.

This explanation, however, though ingenious, does not meet all the difficulties of the question; for besides the heat which would be conducted by the coating of vapor, if the vapor had the power of conducting it (which is possible), there is the enormous quantity of radiant heat, emanating from all parts of the heated crucible.

If a vessel containing water be placed near a fire, it is well known that it gradually becomes warm, and if the fire be a good one, and the distance not too great, the water will shortly boil. The heat which causes the water to boil in this case, is not conducted from the fire to the water through the intervention of the air, since we know that air has no such power; but it is a portion of that which, like light from a candle, radiates from the fire in all directions, and is absorbed more or less completely by any substance which stands in its way and intercepts its passage. Why, then, does not the spheroid of water, sursounded as it is almost completely by an intensely heated metal, absorb the rays of heat which dart towards it from every side, become instantly heated to the boiling point, and dispersed in vapor with explosive violence?

In order to answer this question, it has been stated by some philosophers, that the radiant heat, when it meets with any liquid in the spheroidal state, passes through it without experiencing any interruption, and consequently does not impart any heat to it. A simple experiment is sufficient to show the fallacy of this hypothesis.

If a crucible be made red-hot, and a small bulb of glass containing water be brought near to its inner surface, the water boils violently, owing to the absorption of radiant heat, and notwithstanding the presence of a quantity of non-conducting air between the heated metal and the water. This shows that heat does radiate from the sides of the crucible, and that, too, in sufficient quantity to cause water to boil with considerable violence. If now the same crucible be again heated to an equal degree, and a few drops of water poured in, they at once assume the spheroidal state. Things being in this condition, let the little glass bulb containing water be immersed in the spheroid, and it is found that the water does not show the slightest tendency to boil. The spheroid of water has consequently in some way or other prevented the rays of heat reaching the glas bulb and the water which it contained.

But if, according to this hypothesis, the radiant heat passed through the substance of the spheroid, without being to any extent absorbed or arrested by it, it would obviously reach the bulb containing the water, and cause it to boil with as much violence almost, as it does when no spheroid is interposed between it and the source of heat.

Another mode of explaining the low temperature of liquids in the spheroidal state, is clearly pointed out by the result of this experiment, which proves, I think, beyond all doubt, that bodies in the spheroidal state have, when they have attained their maximum temperature (which we have found to be always lower than their boiling point), the remarkable property of reflecting, almost completely, radiant heat.

A curious variation of the last experiment, tending to the same conclusion, may be made by putting a piece of ice into the red-hot crucible. It instantly absorbs sufficient heat to cause a portion of it to become spheroidal, after which it continues at a temperature of 205 deg., even though a portion of the ice remain unmelted within the globule.

Thus the ice, and afterwards the water, which has an almost perfect reflecting power at 205 deg., absorbs, instantaneously as it were, all the heat necessary to raise it to that temperature, and above which it does not become heated! Why and how is this? are questions which in the present state of our knowledge cannot be answered; and we have here one of those deep mysteries, so frequently met with in our researches into the hidden laws of nature, which baffle and confound the reason, and set at nought, for a time at least, the powers of the human mind.

We have seen that not only water, but also alcohol, ether, and liquid sulphurous acid may be obtained in the peculiar condition which I have, on account of the external form which always attends it, called the spheroidal state. It becomes interesting to inquire whether so remarkable a change may be produced in other liquids.

A great number of experiments have been made with almost every kind of liquid; solutions of acids, alkalies, and salts; compressed gases and melted solids; fats and oils of every kind, both volatile and fixed; and they tend to show that all liquids, with scarcely an exception, pass, under favorable circumstances, into the spheroidal state.

The temperature necessary to produce this effect, appears to bear some relation to the boiling point: those which boil most readily, requiring a lower temperature than the less volatile substances.

That a drop of water or other fluid when in the spheroidal state, is poised as it were, without support, at some sensible distance from the surface of the vessel containing it, may be proved in many ways.

If a spheroid of some opaque substance be formed on a nearly flat surface, and then interposed between a lighted candle and the eye, the image of the flame is distinctly seen between the hot surface and the globule. This effect might be produced if the spheroid were in a state of rapid motion up and down, since the image of the candle, seen during the ascent, would remain visible till the next ascent; just as an ignited point in rapid revolution appears as a circle of light.

That this is not the case, however, may be shown in another way. If silver be touched with nitric acid, it is rapidly corroded, and in a short time dissolved. But if a quantity of nitric acid be poured into a crucible or dish of silver, sufficiently hot to induce the spheroidal state, no corrosion whatever will take place; clearly proving that the acid is at no time in absolute contact with the metal. That this is not owing to any deficiency in the strength of the acid may be seen by placing in the spheroid a piece of cold silver, when violent action of course takes place, nitrous fumes being given off, and nitrate of silver formed.

A remarkable effect may be produced, owing to this repulsion between liquids and heated solids, if a large spheroid of water be formed on a surface nearly flat, and a small bar of white or red-hot iron be then thrust into the middle of it. Contact being impossible between the bar and the water, the latter forms a ring at some little distance from the heated bar, presenting very much the appearance of Saturn and his ring. Whether any real analogy exists between the two effects, or whether the causes be in any way connected, further researches into the nature of that anomalous appendage of the planet may perhaps decide.

I have now passed in review the most important phenomena presented by water and other liquids when thrown into vessels raised to a high temperature.

We found in the first place, that water may be made to assume the globular form, when placed in a cup heated only to 340 deg., which is less than 130 deg. higher than its boiling point; and that the temperature necessary to convert other liquids into spheroids bears some proportion to their several boiling points; that for alcohol being 273 deg., and for ether 140 deg.

Secondly, we found that the rapidity

with which water in the spheroidal state evaporates, is in proportion to the temperature of the heated vessel containing it; but that the evaporation in the spheroidal state is, at a temperature of 400 deg., 50 times more slow than that of ordinary boiling water at 212 deg.

On inquiring into the temperature of liquids in the spheroidal state, we arrived at the remarkable result, that whatever the temperature of the containing vessel may be, that of the spheroids is invariable, and always below their boiling points. Thus a spheroid of alcohol always stands at 170 deg., or 3 deg. below its boiling point; one of ether, is always 5 deg. below, or 95 deg.; and liquid sulphurous acid, which boils at 14 deg., never reaches even that low temperature when in the spheroidal state, but continues far colder than melting ice, even though the crucible in which it lies be all the time at the most intense white heat!

Fifthly, we found, that the only way of explaining this low temperature of spheroids, is to suppose that they have the property of reflecting, in a very perfect manner, the radiant heat emanating from the sides of the hot crucible, and are in this way protected from the scorching rays which would otherwise cause them to burst violently into steam.

In the sixth place it appeared that, with scarcely any exceptions, all liquids may be made to pass into the spheroidal state.

And, lastly, there appeared strong evidence to prove that spheroids are never in absolute contact with the vessel containing them.

Let us now endeavor to draw from our inquiry, something of a practical, and therefore, perhaps, more interesting character, with reference especially to the subject of steam-boiler explosions; a subject on many accounts of so much importance, that no words of mine are needed to enlist your attention for a short time to it.

Until the last few days, I had supposed that no one had attempted, previously to M. Boutigny, to account for the explosion of boilers on the supposition that the water in them passes, under certain circumstances, into the spheroidal state. In this opinion, however, I find that I was partially mistaken; and I feel great pleasure in saying that one of our townsmen, Mr. Robert Armstrong, some few years ago, advanced an idea on this subject, a good deal similar to that of M. Boutigny.

If heat be applied to water contained in an open boiler, the temperature of the water will of course continue to rise until it reaches 212 deg., when the elastic force of the steam is sufficiently great to overcome the pressure of the atmosphere, and the water boils. If the heat be still continued, the whole of the water will, as is well known, boil away, leaving the vessel empty; but as long as any liquid remains, the temperature of the vessel never rises above 212 deg., owing to the absorption of heat by the steam.

As soon as the boiler is empty, however, its temperature of course rapidly rises, and may reach a red, or even white heat, provided the furnace be sufficiently powerful.

If water be now gradually thrown into the overheated boiler, we know from what has already been said, that it will pass at once into the spheroidal state, and will continue at 205 deg., until, from some cause or other, it is permitted to *come in contact* with the heated surface, when violent ebullition immediately takes place, an enormous quantity of steam is instantaneously produced, and, if the vessel be a closed one, as is the case with steam boilers, *an explosion* is the almost inevitable result.

An experiment exceedingly easy of performance is sufficient to illustrate this. Let a large spheroid be formed in a vessel of platinum, or copper; so long as the heat is applied to the latter, the water never shows the least sign of boiling; but if the lamp be extinguished, and the vessel allowed to cool a little, the water suddenly comes in contact with the metal, and an enormous quantity of steam is instantly formed.

A spheroid composed of between four and five pints of water has been, in this way, experimented with, when the sudden formation of highly elastic steam was very striking.

If water be boiled for some time in a copper flask or small boiler, until the whole of the air is expelled, and the vessel be then tightly corked, and the source of heat removed, it is well known that as the water cools, and the vapor condenses, a partial vacuum is formed; and owing to the external atmospheric pressure, the cork is held firmly in its place, and offers considerable resistance to any attempt to withdraw it.

Far different, however, is the effect produced, if, instead of boiling the water in a comparatively cool flask, it be thrown into one which is sufficiently hot to cause it to pass into the spheroidal state.

So long as the flask continues hot, nothing remarkable occurs; but if the lamp be removed, and the temperature of the metal be allowed to fall lower than 350 or 400 deg., a faint noise is shortly heard, and the moment after, a violent explosion takes place, projecting the cork or stopper from the mouth with great force.

Now all this is easily explained. The water, on ceasing to be spheroidal, *wets*, or comes in contact with, the heated boiler, is converted instantaneously into steam, which, being thus generated in vast quantity, finds an outlet at the point of least resistance.

This experiment proves, that if water exists in the spheroidal state in a boiler, and the boiler be allowed to cool, owing to the extinction of the fire, *an explosion* is the almost certain consequence.

A result precisely similar is produced by adding a quantity of cold water to a boiler containing a portion of liquid in the spheroidal form.

If now we multiply a few hundred times the dimensions and capacity of our puny apparatus here, we shall arrive at the size of the steam-engine boilers commonly in use; and when we remember that every cubic foot of water which is in this way suddenly converted into steam, increases in bulk no less than 1,700 times in almost a single second, and, consequently, requires 1,700 cubic ft. of room to contain it, we shall not be surprised that the strongest and best constructed boilers are burst by so sudden and so enormous an expansive force.

But here the question arises—does water really ever become spheroidal in steam boilers? and if it does, what are the circumstances which lead to so dangerous a crisis?

That water contained in boilers does pass to the spheroidal state, there can be no doubt; since we know that sometimes circumstances are such that it could not possibly be otherwise; and, moreover, it has actually been seen to be so. What then are the causes which lead to this occurrence?

The most obvious cause is a deficiency of water in the boiler; owing either to the negligence of the engine man, or to some defect or derangement of the feed pipe. When this deficiency occurs, the boiler, if the furnace underneath be in action, shortly becomes strongly heated, and it is, I believe, by no means an uncommon occurrence for it to reach even a red heat. If water, under these circumstances, be thrown in, the first portion becomes, of course, spheroidal, and continues so, until by the addition of a larger quantity, the boiler be so far cooled as to be unable to maintain the spheroidal form of the water; no sooner is this the case, than the spheroid comes in contact suddenly with the overheated boiler, bursts into steam, and in all probability, an explosion is the result.

Another, and highly probable cause of water becoming spheroidal, I find suggested by Mr. Armstrong, in his excellent work on Steam-Engine Boilers, and which is well worthy of notice. I cannot do better than use his own words. After alluding to the subject of boiler incrustations, and the effect they have in preventing the passage of heat from the furnace to the water, owing to their nonconducting property, he says:

"Under similar circumstances to those just mentioned, there can be no doubt that a portion of the boiler occasionally becomes nearly red hot, although this condition appears extremely inconsistent with the supposition that it is at the same time covered with water; yet we have been compelled to adopt this conclusion from having had ocular demonstration of its possibility, as well as other reasons. We had frequently heard the fact stated by intelligent engine men, and had been called, more than once, to witness it, although even then inclined to consider it a mistake, owing to the difficulty of ascertaining it clearly; for a slight approach to the incandescent state must be nearly invisible, owing to the strong glare of light from the furnace directly beneath, while any degree of heat much higher would be sure to weaken the iron so much as to cause the boiler bottom to give way.

"The probability of boilers sometimes approaching a red heat receives a corroborative proof on examination of the iron plates, in cases where the boilers have bulged out, and which exhibit an appearance well known to boiler-makers, by a peculiar color in the iron surrounding the part which has been red hot.

"Whenever," he continues, "a boiler is seen in this state, of course the only method of avoiding danger is to slack the fire immediately by opening the fire doors. But it frequently happens that the fireman thinks the boiler is empty, and if he has an opportunity he immediately lets into it a quantity of water, when the consequence uniformly is, that the boiler bursts instantly."

The bursting in this case we can now readily understand. It is precisely similar to our last experiment, in which the spheroidal state of the water was destroyed by the addition of a quantity of cold water.

Mr. Armstrong goes on to say:—

"From what we have stated above as the common practice in some districts, we may conclude, that the principal cause of boilers becoming unduly heated, is undoubtedly, in a majority of cases, owing to the interposition of indurated or encrusted matter between the heated iron and the water; and the manner in which those circumstances operate in producing an explosion, appears to be as follows: We have before shown that an internal coating of boiler scale is liable to crack and separate into large pieces, which are thrown off from the boiler with a certain degree of violence, at some particular degree of temperature, depending upon the thickness of the scale, and the kind of substance of which it is formed."

He then proceeds to explain how, by the sudden separation of these pieces of encrusted earthy matter, the water flows upon the overheated metal, when, of course, the result will be, that a portion of the water becomes spheroidal, which, on subsequently coming in contact with the hot surface, is immediately converted into steam.

Seeing, then, the imminent danger which always attends the presence of spheroidal water in a boiler, it becomes a question of the highest importance, whether any means can be devised, which will effectually prevent such an occurrence.

If it were possible to insure a constant, uniform, and never-failing supply of water to the boiler on the one hand, and to prevent the accumulation of earthy sediment or crust, on the other, there would be little or no fear of the water ever becoming spheroidal. But there are, I believe, great and serious obstacles in the way of these conditions being practically complied with; both on account of the liability to derangement which affects most kinds of feeding apparatus, and the great difficulty which exists, both in preventing and removing the deposition of the earthy matters which are found more or less abundantly in most kinds of natural water.*

It has been found that the more smooth and even the surface of a metal is, the more prone is water or any other liquid, on being thrown upon it, to pass into the spheroidal state; and that any great roughness, or especially the presence of sharp points, considerably lessens the danger of such a change. There is, however, a great objection to fixing projecting points in a steam-engine boiler, on account of the difficulty they would occasion in cleaning it out; and the idea occurred to M. Boutigny, which is, I think, a good one, of placing in the boiler loose pointed pieces of iron of such a shape that one of the points should always be uppermost.

Before I conclude I will say one word respecting the possibility of preventing an explosion, even when water *has* become spheroidal in a steam boiler.

And here an experiment which we have already seen will suggest the best mode of proceeding, in order to avert the impending danger. When water was thrown into a hot platinum crucible, and thus made to assume the spheroidal form, we found that so long as the crucible continued hot, the globule floated on its bed of vapor, slowly and gradually evaporating, and showing no appearance even of boiling, still less of passing explosively into steam; but no sooner did we allow the crucible to cool down to a certain temperature, than the water, on touching its still overheated sides, was instantly dissipated in the form of highly elastic steam.

If, then, it be ascertained that the water in a boiler has become spheroidal, the chief care of the engine-man should be to keep up the fire, and also to prevent most completely the influx of any further supply of water; since non-compliance with either of these conditions would cause the cooling of the boiler, the spheroid would then, in all probability, shortly be converted suddenly into steam, and an explosion would be the almost inevitable result. But if, on the other hand, the spheroid be *not* allowed to touch the boiler, it will calmly and slowly evaporate, without occasioning any further inconvenience than rendering the engine

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* As most kinds of spring and river water contain in solution some earthy matters, which are left by the evaporation of the water, giving rise to the formation of sediments and incrustations, it has often occurred to me that rain water might be substituted with great advantage.

comparatively inactive until it has returned to its natural condition.

The advice then relative to this subject, which should be given to those who have the charge of steam-engines, is simply this:—

1st. Be careful that the boiler is kept as free as possible from earthy incrustations, which, if allowed to accumulate, form in fact a boiler of stone inside the iron one, and thus retard the passage of heat from the fire to the water, until the iron has become more or less overheated.

2dly. Never let there be a deficiency of water in the boiler, since, when that happens, the latter may become heated almost indefinitely, and is consequently sure to render water spheroidal when thrown in, when an explosion will be (without great care) almost certain.

And lastly, If it be known that, owing to any cause, the water in a boiler has already become spheroidal, instantly stop the supply of water, and take care that the fire is well kept up until the whole of the water has evaporated; when that is the case, the boiler should be allowed to cool to its natural temperature, when water may be added and the fire re-kindled.

Mr. Stuart, in his interesting "History of the Steam-Engine," speaks of that paragon of human art in the following terms. He says: "It has become a thing alike stupendous for its force and its flexibility; for the prodigious powers which it can exert, and the ease, precision, and ductility with which they can be varied, distributed, and applied. The trunk of an elephant, which can pick up a pin and rend an oak, is nothing to it. It can engrave a seal and crush masses of obdurate metal, like wax, before it; draw out, without breaking, a thread as fine as gossamer, and lift a ship of war like a bubble in the air. It can embroider muslin, forge anchors, cut steel into ribbons, and impel loaded vessels against the fury of the winds and waves.

"It would be difficult," he continues, "to estimate the value of the benefits which these inventions have conferred upon the country. There is no branch of industry that has not been indebted to them; and in all the most material they have not only widened most magnificently the field of its exertions, but multiplied a thousand fold the amount of its productions. It is our steam-engine that has fought the battles of Europe, and exalted and sustained the political greatness of our land; and it is the same great power which now enables us to maintain the arduous struggle in which we are still engaged against the skill and capital of all other countries.

"But these are poor and narrow views ot its importance. It has increased indefinitely the mass of human comforts and enjoyments, and rendered cheap and accessible, all over the world, the materials of wealth and prosperity; it has armed the feeble hand of man, in short, with a power to which no limits can be assigned, completed the dominion of mind over matter, and laid a sure foundation for all those future miracles of mechanical power, which are to aid and reward the labor of after generations."

Such is Mr. Stuart's eloquent summary of the powers and capabilities of the Steam-Engine; words, highly colored, it is true, but which are the words, nevertheless, "of truth and soberness."

We must not forget, however, that the possession of such a machine imposes upon us who benefit by it, responsibilities of no common kind; and that it is our duty, no less than our interest, to endeavor, by all the means in our power, to prevent the occurrence of those appalling explosions (still, alas! so frequent) which are attended with such fearful consequences to human life.

CALIGNY'S APPARATUS FOR RAISING WATER OR FOR DRAINAGE BY THE ACTION OF WAVES.

Translated from "Les Mondes."

Since the 22d of last July Caligny has published five notes on the motion of waves in the "Comptes Rendus" of the Academy of Sciences, forming together a complete memoir. It is necessary to read all to get a precise idea of their bearing. The note of July 22d, deals principally with experiments and observations upon the effect of waves, and of currents in the funnel-like passage formed by convergent dikes; as projected by the Captain of the Cialdi, for the purpose of destroying or preventing the formation of sand bars.

The note of October 7th, is an investigation of the system of M. Cialdi, *i. e.*, of the effects of the lateral communication of the movement of a current of water across a reservoir. The mode of formation of sand bars is favorable to the operation of Cialdi's system.

The note of January 6th is equally important and interesting. Its special object is the study of the alternating currents that result from the blows of a water-ram.

That of the 17th of February refers to the works for drainage of the marshes at Ostia, by Moro, upon a principle like that published some years ago in the "Bulletin of the Philomathic Society" of Paris. By means of the alternating rise and fall of the level of waves, he caused the lowering of the water in the marshes below the level which the sea would have had, if there had been no waves. Notice is taken of the effect of alternating currents produced by waves on inclined shores. He mentions the fact that Moro by means of Cialdi's method removed a bar at the mouth of a canal, and adds that Moro believes it could succeed at Port Said.

Caligny's last note makes exposition of the most essential principles proposed by Moro, and which are to be applied both to drainage and the raising of water by means of waves.

SCREW PROPELLERS.

From "The Engineer."

Mr. Griffiths is well known as the inventor of one of the best, or at all events the most popular, screw propellers ever designed, and this, taken in conjunction with the fact that his experience is considerable and his judgment sound, entitles what he pleases to say on the subject of screw propulsion to much consideration. But Mr. Griffiths, nevertheless, is not infallible, and we fancy that the theory he has recently formed concerning the action of screws—a theory based on elaborate experiments with models—will hardly be accepted as satisfactory by those engineers who have devoted any attention to the propulsion of ships. In brief, Mr. Griffiths' statements go to the effect that by placing one screw in a tunnel near the bows of a ship, and another screw in the ordinary place at the stern, he effects a saving of 50 per cent. in the power required to drive a vessel through the water. This is a very remarkable proposition, involving issues of enormous magnitude, and so far as is apparent from Mr. Griffiths' evidence, it is unquestionably true. Nevertheless, we refuse to accept it as accurate. We hold, on the contrary, that by no new arrangement of screw is it possible to effect a saving of anything like 50 per cent. on the power required to propel a given hull of the best shape through the water, provided care be taken in the first instance to fit her with a normal screw suitable to her requirements. It is possible that the normal single screw used by Mr. Griffiths in his experiments does not at all suit the lines of the model—5 ft. long, 7½ in. beam—to which it is fitted; and before Mr. Griffiths can claim any advantage for his tunnel system, he must show that it was impossible to use a single screw of any shape or pitch from which equally good results could not be got. The model was actuated by spring-driven clockwork; the propelling force was therefore constant under all circumstances, and the efficiency of the propeller was measured by the distance traversed. Now, with twin screws, Mr. Griffiths found that his model ran about 85 ft. in a minute, with 600 revolutions, while with a screw in the tunnel near the bow, and another at the stern, the model ran 95 ft. to 100 ft. in a minute with 600 revolutions. The data, it will be seen here, are incomplete, and cannot be accurately compared, because although the propelling force of the spring driving the clockwork was constant, it is evident that no information is supplied concerning the loss due to friction of the gearing, which, in such small machinery, must be considerable. It is tolerably clear that the loss due to this cause would be greater as regards the twin screws than in the case of the double screws fitted on the new system, because in the latter case both screws might be fixed on the same central shaft, whereas with the twin screws two additional shafts and two additional wheels would be required. In this respect, to begin with, the whole value of Mr. Griffiths' experiments, in a scientific sense, is neutralized. In order to prove anything concerning the efficiency of the two systems, he must also prove that the force actually expended on the twin screws was identical with that spent on his two screws. It may be said that the error would be but small, and could not produce much effect; but this is contrary to all experience. It is known that with screws an apparently small variation in power will produce very considerable alterations in result; and there should besides be no errors that can possibly be eliminated in experiments such as Mr. Griffiths conducts. To show how easily variations in net power may escape unperceived, we may state that within our own knowledge a large steamer recently gained nearly a knot an hour in speed by being re-engined. The propeller remained the same, and the indicated power of the new engines was practically identical with that of the old engines. These last were very complex and had very short connecting rods. The new engines were very simple and had long connecting rods, and there can be no doubt but that the *indicated* power remaining the same, the *net* power was much greater with the new than it was with the old machinery. There are other reasons, however, why Mr. Griffiths' result should be regarded with extreme caution. That which he proposes to do has, in a sense, been tried over and over again. It may be a new thing to fit a secondary screw in a tunnel running the length of a ship, retaining the original screw; but it is not a new thing to put a screw in a tunnel. Neither is it a good thing. It has been tried repeatedly, and always resulted in failure. Mr. Griffiths must explain how he has obtained results which are totally at variance with those got by every other person who has tried to work screws in tunnels. It is possible that Mr. Griffiths' system has done well, because his tunnel, cut through the length of the ship, permits the accession of plenty of water to the fans of the stern screw. But the fact that the more water a stern screw can get the better, has been known for years; and Mr. Froude showed long since that a remarkable increase in efficiency could be realized by working the screw far astern of the hull, say by extending the propeller shaft to a distance of 20 or 30 ft. behind the rudder. It is obvious, however, that, no matter what advantages might be gained in this way, the expedient is wholly inapplicable to sea-going vessels; and it has yet to be proved that Mr. Griffiths' tunnel could be tolerated in an ocean steamer. That Mr. Griffiths' experiments, as far as they have gone, are interesting we do not dispute, but they require to be extended and verified before they can be accepted as in any mode or form conclusive.

It is not too much to say that no sound or accurate theory of the screw propeller has yet been laid before the world; and the result is that the forms given to propellers by different inventors may be counted by the hundred. The broad principles governing the action of screws, however, may be easily laid down. A ship is caused to move forward because a column of water is made to move astern, and the heavier the column of water the slower its speed astern, and the more directly its line of recession is in the plane of the ship's longitudinal axis, the more efficient will the propeller be. It may be assumed, therefore, that the true work done by either screw or paddles consists in putting a body of water in motion, the forward movement of the hull being simply an accident of that motion; and in designing either screw or paddle-wheels the inventor should concentrate his attention on the water in the first instance as the thing to be moved. Now the paddle-wheel, if well made with feathering floats, can be made to expend a very large proportion of its energy in driving water backwards, especially if made of large diameter, and with very wide and shallow floats. The loss of energy is represented principally by the lifting up water at the back of the wheel, and by the scooping out of a cavity or depression in the liquid beneath the axis. In the case of the screw, however, matters are different. Not only is the screw called upon to drive a large body of water astern, but it also imparts a rotary motion to this column, which, generating—if we may use the word—centrifugal force causes the divergence or spreading of the column; but all the power expended in imparting rotary motion to the column of water is wasted. Let us suppose, for example, that the blades of a screw are flat planes, and that they are twisted round so that these planes are parallel with the keel. It is evident that if caused to revolve, they would offer great resistance to the engines, and would put large bodies of water in motion, but the hull would remain at rest. Let the blades now be turned at right angles to the keel, and the resistance will be little or nothing; no water will be moved, nor will the ship. If we give the blades an intermediate position we have a screw. One portion of the power is spent in causing rotation of the water, another in driving the water astern. The first is waste, the second is utilized. That screw will, broadly speaking, be the best, that prevents the waste of power by the radial divergence of the water. Various schemes have been tried to effect this end; one, for example, Ericsson's, consisting in placing two screws on the same telescope shaft and causing them to rotate in opposite directions. It is impossible for the first screw, however, to neutralize the effects of the second; and although good results have been obtained from this system, no advantage has been derived which compensates for the complication. Screws have been mounted in tubes to prevent the divergence of the water, but it was forgotten that the water rotates in the tube and escapes from it in rotation, and consequently the moment it quits the tube divergence and loss take place. The scheme has not succeeded. Very recently Dr. Collis Browne has produced a very singular screw—something, in a sense, like the double Mangin screw used in the French navy. The peculiarity lies in the curves given to the blades, which it would be hopeless to attempt to show by an engraving. The intention of the inventor is, however, to gather up the water towards the centre by the first screw, and to throw it right on to the blades of the second screw. Both are fixed on the same shaft, and of course both revolve in the same direction. We believe that the principles involved are now being mathematically investigated, and we understand that Dr. Browne has succeeded in beating every other screw with which his has competed, but enough is not yet known of the propeller to enable us to pronounce any decided opinion on its merits. The truth is that for every form of hull there is a screw better than any other, and this complicates experiments with screws terribly.

Leaving the realms of theory, it will not be out of place to say here that the Hirsch screw appears at present to enjoy a better reputation than any other. At all events, it has been adopted by the Admiralty as the future screw of the British navy—at least till something superior is brought out —and we therefore give a drawing of the screw in its most improved form at page 423. This propeller has now, we understand, been fitted to eighty-six ships, representing an indicated horse-power of 151,374. There appears to be no doubt that this screw is most efficient, and that it secures an almost total absence of vibration. The curves of the blade have been deduced from practice with great care, and on them the good qualities of the propeller apparently depend. It must not be forgotten, however, that difficulties attend us in attempting to estimate the advantages of this as of any other screw. Thus, it will be seen that we have in it four narrow, scimitar-shaped blades. This screw has freqently been tried against two-bladed propellers, which it has beaten; but this is perhaps scarcely a fair comparison. A four-bladed propeller may be better than a two-bladed propeller, and yet very different from the Hirsch screw. However, Mr. Hirsch appears to have obtained a legitimate success, and we shall say nothing which may appear to detract from it in the absence of any facts tending to show that its merits are overrated by shipowners generally and our own Government in particular.

THE APPLICATION OF ACOUSTIC, OPTICAL, ELECTRIC AND MARITIME TELEGRAPHY TO NAVIGATION AND METEOROLOGY.*

By His Excellency Don ARTURO DE MARCOARTU, Ex-Deputy to the Cortes, M. Inst. C. C.

From "The Engineer."

Electric telegraphy commenced by uniting together towns situated in the same State; it afterwards brought bordering nations into communication; further on—and this was the principle of a great revolution —submarine cables crossed straits; and finally, during the last few years, it has ended by enlacing distant continents, islands,

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* British Association, Section G.

and coasts in all directions. But, up to the present time, electric telegraphy requires a conducting circuit to unite the two stations; and the prodigies of electricity terminate wherever there is a solution of continuity in the conducting wire. Electric telegraphy cannot go beyond this. For this reason the electric telegraph, which places Great Britain and the United States in complete and permanent communication, is powerless for connecting any of the coasts of these nations with the vessels which are navigating upon the very ocean in whose depths the Anglo-American cables are lying, even when such vessels are but a few miles from the coast.

Acoustic and optical telegraphs (the former hardly ever used at the present day, the latter never), while far more limited in their reach than the electric when the latter can establish its conducting circuit, do not demand this condition for their employ; and hence it is that they may be utilized for the purposes of oceanic telegraphy. An oceanic and atmospheric telegraphic service would require fixed electric stations upon the coast, floating stations provided with electric apparatus for communicating with the coast, and with acoustic and optical apparatus for communicating with the sea; and bodies navigating alike in the ocean as in the air, which, impelled by the waters of the former or by the winds of the latter, are capable of deciphering the measure of the velocity of the oceanic and atmospheric currents. For greater utility in navigation and meteorology, the telegraphic floating stations ought to be established upon capes, in islands, straits, canals, banks, at the mouths of rivers, and in the principal points of passage of commercial movements, and the principal currents of the ocean. The establishment of these floating stations, or moorships, will be more or less difficult, more or less costly, but they will be practicable; and only will be impracticable at but few exceptional points amongst those frequented for purposes of navigation.

It has been asserted that the cannonade of Waterloo could be distinguished at Dover; that that of Carlscrona was heard across the southern extremity of Sweden as far as Denmark, a distance of 120 miles; and that the sound of a sea-fight between the English and Dutch in 1672 was heard across England as far as Shrewsbury, and even in Wales, a distance of 200 miles.

Dr. Arnold relates, that while coming from South America to Europe, and at a distance of 100 leagues from shore, he heard, while standing in the focus of the concave side of one of the sails of the ship, the sound of the bells which were ringing in celebration of a feast at Rio Janeiro. And although these and other circumstances which have been related may not be accepted as indubitable facts, yet authentic experiments have demonstrated the great distance to which sounds are capable of being conveyed through the air, water, snow, or ice.

Their transmission through water is very remarkable. Collandon heard by means of a trumpet submerged on one shore of the Lake of Geneva, the sound of a bell vibrated beneath the water, on the opposite shore, at the distance of 9 miles. I myself heard, a fortnight ago, conversations at Lough Cutra, in Ireland, at a distance impossible were it not for the stillness and evenness of the surface of its waters.

In order to judge of the transmission of sound over the ice, it is enough to remember that Parry relates in the account of his Polar expedition that two men conversed distinctly at a distance of a mile and a quarter. Sounds, after being transmitted through tubes, become wonderfully augmented in volume. Boward states what is correct, that the report of a pistol fired at the mouth of a tube resembles that of a cannon at the other extremity. Jobard placed a watch, the ticking of which was not distinguishable at 30 centimetres distance, in the interior of a tube; and the sound of its movement was then perceptible at a distance of 16 metres. It was the belief of Rumford that the human voice could be rendered audible for a distance of hundreds of leagues by means of tubes. The tubes best adapted for the conveyance of sound are the metallic ones, of copper, iron, zinc, etc.

In order to produce sound at a certain distance it is necessary to originate a direct or indirect shock acting by means of a combination of strings or hammers, or compressed air, or steam, upon vibratory bodies. The force of the motor-agent and the nature of the vibrating body will determine the nature of such sound which is capable of attaining developments not generally employed up to the present time.

For to diversify the volume and tone, besides the nature of the vibrating bodies, the diameter and material of the apertures of exit can be likewise varied. If it be desired to transmit the sound to considerable distances, it should be collected and made to pass through an acoustic tube; and if upon the emission of the sound it should be desirable to concentrate it in a given direction, in order to increase its compass in such direction, it will be advisable to receive the sound emitted at the extremity of the tubes by means of a paraboloid reflector, the axis of which must be parallel to the desired direction. The variety of volumes and tones producible according to the variety of the vibrating bodies, and the diameters of the orifices giving exit to the sound, and the alternate or intermitting repetitions at longer or shorter intervals of time which may be originated by the combination of the said sounds, will create the elements requisite for the formation of a telegraphic vocabulary.

Three important series of distinctions are capable of being marked by three descriptions of sound only: one of them sharp, as a whistle; another, the sound of a bell; and the third an explosive detonation. Fine weather, for instance, might be indicated by a whistle, which might be made audible for a short period every hour; a bell might give warning of bad weather by means of a scale, according to which, when rung respectively, for the minute with a silent interval of ten minutes; for two minutes with an interval of five; or continuously,—signals of bad weather, progressively becoming worse, might be indicated. The prevailing direction of the winds might be announced by combining the whistle and the bell.

It is easy to perceive that without the necessity of having a person to produce the sound of the whistle and bell, they may be made to vibrate by means of an automotive apparatus of clock-work, which shall place them in communication with a clock every time the weather changes. It will be enough that a clerk should initiate such movements, which would continue until he interrupts them in accordance with the respective atmospheric changes taking place.

From the floating stations, which, on many occasions, should be placed thirty miles, at least, distant from the coast, pneumatic tubes terminating in a floating buoy may be carried out so as to extend several miles further into the sea. These tubes will convey to the buoy the sounds produced by the floating station; and the buoy, with its paraboloid reflector, will direct them seawards. The acoustic tube which unites a land or floating station with a floating buoy, should be metallic, and ought properly to be covered so as to isolate it from the bottom of the sea. Should the tube not be very long, wires might be made to pass through it to operate on the percussion apparatus for producing the sound in the floating buoy; and whether long or short, the tube may always contain a wire conductor of electricity when it may be requisite to produce a detonation with an explosive agent deposited in the floating buoy. The same acoustic tube may on certain occasions be utilized for sending through it to the floating buoy (employing well-known pneumatic principle), latest intelligence in letters, or latest telegrams for steamers at sea; or the boats belonging to the said vessels might place the said latest news in chambers expressly formed in the buoys, and by means of the vacuum produced by a steam engine stationed at the floating or coast station, receive urgent letters or telegrams long before the vessels themselves enter the ports. It does not seem impossible to employ under advantageous economic conditions the force of the sea itself for the service of the tube.

In order that the vessels may be in telegraphic communication with the coast or floating stations, they will have to carry one or more paraboloid reflectors, gyrating round a vertical axis, so as to be placed in any direction of the wind. The whistle and bell will be placed in the focus of these reflectors. A practised observer, when placed within the focus, will hear the signals sent from either land, floating, or navigating stations at several miles distance, and will in his turn cause every other telegraphic station to hear the signals addressed to it.

If two powerful telescopes whose optical axes correspond with each other are fixed, and a light, either solar, reflected, or artificial, be presented before the eye-piece of one of these telescopes, the said light will be distinguished at many miles distance by the other telescope like a brilliant speck. By producing combinations of such a light with eclipses, and varying the time such light is shown and the duration of such eclipses, a telegraphic language might be formed, which, in a clear atmosphere and with a light expressly prepared, would be distinguishable at several miles distance. But when one or both telescopes are in motion the communication is almost impossible. In this case it becomes necessary to have recourse to reflecting and catadioptric apparatus, as in the lighthouses, and construct a telegraphic vocabulary, by the use of white, green, and red shades, their relative position, their color, and the duration of their respective appearances and eclipses. These optical signals, when made from the coast or floating stations, will be discoverable from vessels, by the aid of telescopes of considerable power, at a distance of several miles. And if vessels were themselves to carry reflecting and catadioptric apparatus they could bring them into operation in case of necessity.

On various occasions bottles have been thrown into the sea for the purpose of observing the path described by them when left to be borne by the currents of the ocean.

It would be very interesting to organize a carefully prepared series of observations, whereby bottles, balloons, and buoys with self-drawing thermometers, containing, besides a note of the geographical point where they have been immersed, notices of the state of the tide, the temperature of the water and of the atmosphere, tbe intensity and direction of the wind, and other meteorological data of the locality, might, at at the same astronomical hour, be thrown into the sea at different points, say at the equinoxes, solstices, and other seasons of the year. In the same way small aerostatic balloons, conveying useful memoranda of the state of the weather at the place from which they are launched into the lower couch of the atmosphere, might be arranged so as to furnish us with some knowledge of the movements of that couch.

Within the greater portion of the customary maritime routes, which comprehend a zone of thirty miles in breadth, ships might once a week, at least, be placed in communication with the whole world if such ships were supplied with telegraphic apparatus; and there are some routes within which the navigation might be even in daily communication all over the entire globe. Whatever might be the circumstances of the weather, it would be advisable that vessels, although not distinguishable at first sight, should communicate at least at four fixed periods daily. At seven, morning and evening, and twelve noon and midnight, ships might make acoustic and optical signals in all kinds of weather; and in order to observe and receive them severally, it would be proper, for example, that vessels proceeding in directions towards the south and west should make their signals some minutes before the said hours, and that vessels going towards points of the north and east should make theirs some minutes after the same.

At a later period, in 1863, my expectations as to the future of submarine telegraphy were published in a volume printed at New York. After exhibiting the importance which might be rendered by the oceanic telegraph to navigation, my words then were:—

"Every year there are exposed to the dangers of the seas on the Atlantic some 100,000 vessels of 11,000,000 of tons burthen, coastwise and on the high seas, with several millions of souls, passengers and crews, and more than $400,000,000 in value; the annual losses are estimated at from $2,000,000 to $20,000,000. The insurances paid by this amount of shipping during this not long period are more than sufficient to establish a submarine telegraphic net that would give it real security, and free it from maritime disasters. In that day when said submarine net shall unite the coasts and principal islands of the Atlantic, a much easier and cheaper enterprise than it is generally believed to be, and much more humanitarian than it is commonly esteemed—the English, American, French, and Spanish mail packets and vessels, both steam and sailing, of all parts of the world, will find in their ports telegraphic despatches concerning the state of the atmosphere and of the seas which they are about to cross, and into which they now enter, and frequently to meet with certain death. Without being obliged to touch at the telegraph stations, vessels may receive optical signals on the clear seas, or acoustic signals in foggy weather, which would communicate to them (in the same manner in which railroad trains are signalized) the three states of the sea: 'proceed,' 'caution,' 'danger.' The passage of the vessels seen from the stations through powerful telescopes would be announced in telegrams to the many interested and loving ones which the vessels of our day, in all parts of the world, always leave behind them. The want of provisions or the accident to machinery, etc., which so often occur on board vessels, would at once be communicated to the consignees, who would, from their counting-rooms, send such orders as might be best for their interests."

When, then, indicating one of the most noble and humanizing of the future uses of the submarine telegraph, not a few of its readers must have conceived that prophecies founded upon a future event appearing at the moment more doubtful than realizable—the telegraphic union of both worlds—were merely fantastic dreams. The prediction of the weather and aerostation or aerostatic navigation are two problems, the solution of which has been long earnestly sought, and especially at the present time; yet they are both of them alike problems of possible solution under certain and determined conditions, having amongst them certain common relations, and demanding meteorological observations and studies which have been scarcely hitherto initiated.

Arago has absolutely denied the possibility of solving the first, and for the purpose of demonstrating the credulity of the human mind in respect of the marvellous, published the following anecdote, to which Lagrange drew his attention:

"The Academy of Berlin derived formerly its principal revenue from the sale of its almanac. Ashamed at seeing figure in this publication predictions of every kind, made by chance, or which at least were not founded upon any acceptable principle, a distinguished savant proposed to suppress them and to replace them by clear, precise, and definite information upon objects which seemed to him more interesting to the public. The reform was tried, but the income from the almanac was so diminished, and, consequently, the revenues of the Academy were so enfeebled, that it became necessary to return to the former errors, and to give again predictions in which the authors themselves did not believe."

But in spite of the weighty opinion of Arago, it is not difficult to comprehend that the weather, although the result of multifarious, complicated, and at the present day partially unknown forces, is yet in all its vicissitudes produced by specific causes; and that the very same phenomena of weather are reproduced when the intensity, action, and combination of these elements are repeated, and when the same conditions for the elaboration and coincidence of the said forces of nature exist.

We are not called upon to deduce, because our means of observation are at the present day few and imperfect, that it is not possible to discover certain primordial laws which regulate the variations of the weather, especially in the cases of sudden changes and storms, particularly now, when, thanks to telegraphy, the recurrence of a tempest may be known from its very commencement to other parts of the globe, and great catastrophes be thus prevented. Although with very limited resources, and without any organized and effectual co-operation on the part of vessels navigating, the Meteorological Committees of Great Britain, the United States, France, and Germany, have rendered the most important services to navigation and humanity in general by diminishing the number and extent of disasters and misfortunes otherwise inevitable. At the present moment it is far easier to understand how the telegraph may render important assistance to meteorology by announcing the weather prevailing at determined points, under marked conditions, and within certain limits. As soon as it shall have become feasible, over the whole extent of the globe, throughout her seas and continents, to observe simultaneously and at moments which have been pre-arranged, the degree of pressure and hygrometrical condition of the atmosphere; the evaporation which takes place from land and water; the electric state of the air and earth; the velocity, direction, and temperature of the winds and currents; the clouds, rainfalls, inundations, hail and snowstorms, dews and frosts, the earthquakes, and the sanitary condition and movements of epidemics amongst the nations; and when within brief intervals of time the whole system of terrestrial, fluvial, and maritime telegraphs shall interchange this copious stock of details for aiding the study of the laws of nature, it will become possible to predict in a certain measure both atmospheric and maritime changes, and the character and progress of epidemics. Then the difficulties of maritime and aerostatic navigation will be sensibly lessened.

It is a subject for regret that the last North American storm—supposed to have been one of the most terrible ever occurring, and from the consequences of which a dozen Transatlantic packets must have suffered more or less—was not, for want of means for the purpose, adequately observed, so as to have furnished a mass of data of a kind in which we are unfortunately deficient. Ocean telegraphy upon the high seas, limited at the present moment to the almost primitive system of flag and rocket signals, is destined to make giant strides within the next few years; I shall not be surprised if, by the aid of oceanic and meteorologic telegraphy, a day is at hand when the currents and winds about to be encountered by the mariner will be to him as well known beforehand as the inclines and curves of a line are to the engine driver of a railway train. No cyclone can then engulf a ship by surprise.

I trust I may be permitted to conclude by repeating the hopes I enunciated in a work published at New York, as to the then future of submarine telegraphy now so happily realized.

"The enterprise is both useful and necessary."
"The enterprise, economically and physically speaking, is possible."
"The enterprise will be accomplished."

And in the coming day of the oceanic telegraphy, we may repeat the following words of Psalm xix.:—

"3. There is no speech nor language,
where their voice is not heard."
"4. Their line is gone out throughout all the earth,
and their words to the end of the world."

POLLUTION OF RIVERS, AND ITS PREVENTION.

From "Iron."

The vast increase which has taken place during the last few years in the mining and manufacturing industries of Great Britain has far outstripped all the precautions that the Legislature has at any time enacted should be taken to prevent the fouling of the rivers of the country, by the pouring into them of the refuse incidental to manufactures of all kinds. But at no time have we, or our ancestors, been sufficiently jealous of the purity of our streams. Pure water is the prime necessity of man's existence. He wants it for his own use, to drink and to wash in; he wants it for his cattle; he wants it for his crops; water is the great natural purifier of the air; pure water is necessary to the existence of fish; in fact, without water there can be no life. Whatever legislative enactments have been made, have been passed, not with a view to the general sanitary condition of the country, but with some special and perhaps minor object; and no general law on the subject is in existence. The Thames has its special Conservancy Act, but the other rivers are left comparatively unprotected.

When Acts have been passed, such as the Act of 1862, for preventing the pollution of the Mersey and Irwell, they are practically inoperative; in other cases the measures adopted are curative, not preventive. Instead, for instance, of preventing the passing of solid refuse into rivers, large sums of money are annually spent in dredging, in order to preserve the requisite depth of water in our navigable rivers. Other Acts, again, have actually tended to this evil. The Alkali Act, passed in 1862, with the view of preventing the escape of noxious vapors into the atmosphere, has resulted in the discharge of the gases, in a condensed, solid state, into the rivers.

The Water Works Act (10 & 11 Vict., c. 17) enacts (secs. 61–65) that no stream, reservoir, or aqueduct, belonging to waterworks or reservoir companies, shall be polluted in any way, under a penalty of £5, and £1 for each day during which the offence is continued. Owners of gasworks permitting any foul liquid or solid matter to flow into such waters are subjected to a fine of £200, and £20 a day during the continuance of the offence. The Nuisances Removal (Scotland) Act of 1856 (19 & 20 Vict., c. 103, sec. 19) prohibits the placing of gas, naphtha, vitriol, or dyestuffs, or their refuse, into waters, under a penalty of £50 for every such offence and £5 a day during its continuance. The Malicious Injuries Act (24 & 25 Vict., c. 97, sec. 32) and the various Salmon Fisheries Acts of England, Scotland, and Ireland, contain clauses against the pollution of rivers, which were especially framed in the interests of the fish and their proprietors. But these Acts are not sufficiently comprehensive to prevent the nuisance they were intended to abate. Their provisions in some cases can be easily evaded, and the machinery for carrying them out is not sufficient. But, even then, many rivers would continue to be polluted which would not come under their special care, and a comprehensive general law on the subject is absolutely necessary.

The inspectors and commissioners of salmon fisheries, and the local boards of conservators, throughout the kingdom, do considerable good in their endeavors to abate the nuisances caused by the pollution of our rivers, but where they succeed in their efforts their success is but as a flea-bite on the enormous masses of pollution, liquid and solid, that are being daily poured into our rivers. They do better work in making the public aware of the injury that is inflicted by the, in many cases, preventable and frequently wasteful flow of various pollutions into the streams. The following catalogue of various causes of pollution, reported by these officials as existing almost unchecked in different parts of the kingdom, will give some idea of the dangers we are incurring and the waste that is taking place. In Scotland, Messrs. Buckland and Young, in a report on the salmon fisheries of that country, enumerate the following pollutions as occurring:—Chloride of lime from paper mills; bleach works' refuse; paraffine; naphtha; town sewage; dye-works' refuse; distilleries' refuse; sawdust; coal-pit water; mine water; factory refuse; lint steeping; sheep washing; starch works' refuse; tanyard refuse; and many others.

In Ireland the water from flax works may be added to the above list, whilst in England and Wales the sources of pollution are innumerable. China clay works, tin plate works, chemical works, "hush" of the deadliest character from mines of all kinds, quarries, oil works, print works, in addition to the above-named sources of pollution, add their quota to the general work of destruction. There is hardly a pure river in the country, and the Conway may be said to be the only stream that has not seriously suffered.

Some rivers are actually named from the appearance they present in consequence of the pollutions that are poured into them. The Redbrook, in South Wales, is red with the refuse from the plate works; the Blackburn and Devil's water in Northumberland, are as black with coal washings as ever water so named could be imagined. The Whitebrook, a tributary of the Wye, is white with the refuse chloride of lime from a paper mill.

Any one travelling in the manufacturing or mining districts cannot help noticing the thick discolored streams of poisoned mud, miscalled rivers, which, but for these frightful pollutions, would be pure limpid brooks, abounding with life and producing a supply of clear drinking water. We do not need the reports that are daily published of the destruction not only of vegetation, fish, birds, and animals, but even human beings, by polluted water, to know that this state of things ought not to be. The rivers were never intended to be turned into sewers, and it is the duty of every one to consider the public good, the general health and welfare of the country, before the minor questions of personal benefit; and manufacturers and mine owners—all who deal with noxious matters—should use every endeavor to utilize such matters, or, at any rate, to nullify their evil effects before they go the length of pouring them into the rivers.

The Royal Commission on the pollution of rivers has been taking evidence on this subject for several years past, with the object of legislating on this question; but they have not yet finished their inquiries, and their useful recommendations for diverting pollutions from rivers remain ignored. But the question has become too pressing for further delay, and a Bill was introduced last session into the House of Lords, with stringent enactments for carrying out this much-needed reform. Penalties were proposed upon "every person who places or throws, or causes to be placed, thrown, or to fall, or knowingly or negligently permits to be placed, thrown, or to fall into any river the solid refuse of any manufactory, or any rubbish, cinders, sawdust, or any other solid matter or substance whatsoever, to such an extent as either to interfere with the flow of or to pollute such river," or, who "opens into any river any sewer, drain, pipe, or channel, with intent or in order thereby to provide for the flow or passage of sewage, or of any other offensive or injurious matter; causes or without lawful excuse (the proof whereof shall lie on the person accused) suffers any sewage or any foul, offensive, injurious matter to flow or pass into any river through any sewer, drain, pipe, or channel not at the passing of this Act used for that purpose." Filthy or noxious water or other liquid or washings of any trade, business, process, or manufactories, or any polluting liquid, it is proposed should be forbidden to be carried into rivers.

Of course a standard of purity is necessary in legislation of this kind, and accordingly the following was incorporated in the Bill as a definition of polluting liquids, based upon the recommendations of the Rivers Pollution Commission:—

(1) Any liquids "containing in suspension more than three parts by weight of dry mineral matter, or one part by weight of dry organic matter, in 100,000 parts by weight of the liquid; (2) containing in solution more than two parts by weight of organic carbon, or three parts by weight of organic nitrogen, in 100,000 parts by weight of the liquid; (3) which exhibits by daylight a distinct color when a stratum of 1 in. deep is placed in a white porcelain or earthenware vessel; (4) which contains in solution in 100,000 parts by weight more than two parts by weight of any metal, except calcium, magnesium, potassium, and sodium; (5) which in 10,000 by weight contains, whether in solution or suspension, in chemical combination or otherwise, more than .05 part by weight of metallic arsenic; (6) which, after acidification with sulphuric acid, contains in 100,000 parts by weight more than one part by weight of free chlorine; (7) which contains in 100,000 parts by weight more than one part by weight of sulphur in the condition either of sulphuretted hydrogen or a soluble sulphuret; (8) possessing an acidity greater than that which is produced by adding two parts by weight of real muriatic acid to 1,000 parts by weight of distilled water; (9) possessing an alkalinity greater than that produced by adding one part by weight of dry caustic soda to 1,000 parts by weight of distilled water; (10) exhibiting a film of petroleum or hydrocarbon oil upon its surface, or containing in suspension in 100,000 parts more than .05 part of such oil."

The Local Government Board was to have power to alter the definitions of a polluting liquid as described above, and to diminish or increase their stringency as they may think necessary. The penalties are not to apply where the pollution was caused by excessive rainfall or discharge of storm water, or where the best practicable means have been adopted for its prevention. Notice is to be given of the time at which any pollution is to be discontinued. This time can be extended by the pollution authority if it is found to be necessary or desirable.

The Bill, though it passed a Second Reading in the Lords, was unfortunately too late to become law last session; but we have given the above details of its provisions, as we understand that it is to be introduced in essentially the same shape next year.

We trust that, in the interest of every member of the community, this Bill may become law; and we shall now endeavor to show that it will be to the advantage of manufacturers themselves to dispose of their refuse matter in some other way than pouring it, just as it leaves their hands, without any attempt at purification, into the rivers. We hope that they will not offer a factious opposition to a measure of so universally beneficial a nature, on the plea that the attempt to deal with pollutions will stand in the way of the full development of their manufactures, and impede commercial enterprise. On the contrary, in many cases, a new impulse will be given to commercial enterprise, and new industries will be developed, while the more indirect gain that they will derive from the purer state of the rivers will, in all cases, repay any outlay that may be occasioned. The Bill was prepared under the auspices of the Fisheries Preservation Association, of which the Duke of Northumberland is President; and is supported by a society headed by Lord Polwarth, which has been instituted in Edinburgh for the express purpose of taking measures to remove impurities from our rivers.

The report of the first meeting of the Rivers Purification Association, as this society is named, has lately been published, and gives as concise a summary as has ever been issued of the various processes in actual use for the treatment of one great source of pollution—viz., sewage. Hitherto sewage has been the chief enemy that has been attacked; and we observe, in looking through the report, that all the remedies of which sketches are given are mainly intended as means whereby this particular nuisance shall be kept out of the rivers and turned to advantage. Descriptions of no less than eleven systems of dealing with sewage, with their special advantages and shortcomings, are given. The names of such men as Mr. Wm. Hope, Mr. Baldwin Latham, Mr. Bailey Denton, Dr. Anderson, Mr. McLagan, M. P., are sufficient to show that the knowledge and experience of thoroughly practical men will be brought to bear on the good work which the committee appointed by the Association have set themselves to do. Some of the papers and reports read give most interesting statistics as to the various systems now in use—

systems at present existing more as models and specimens than as actual and accomplished successes. One gentleman waxed poetical on the question of dry earth-closets, quoting from Shakespeare, Scott, Prior, and Milton in support of his system; but it is not in isolated processes that ultimate success will be found; rather, as Mr. Baldwin Latham said, "a combined system will probably be that which will be adopted by towns." He was speaking purely of sewage; but the other and greater evils from the above-mentioned sources must not be neglected.

It is not necessary here to enter into the sewage question; every one acknowledges nowadays that the proper place for the sewage is the land, not the water. The question is, how shall the principle be carried out? Irrigationists and precipitationists may fight over the bone if they will. It has already been satisfactorily shown that the sewage can be profitably utilized, so we need not step in and discriminate between the respective merits of the various systems. It is our task, rather, to point out means by which other and more serious modes of pollution may be profitably utilized, to the actual pecuniary benefit of those who will only adopt those means.

The most serious kinds of pollution are those containing chemical solutions, which can only be treated by a chemical process neutralizing or extracting the poison, otherwise there is hardly any kind of liquid refuse that cannot be purified by filtration or subsidence. The refuse water from dye works, print works, and bleach works can be so purified by filtration, when in the foulest possible state, that it may be turned without offence into the river. The experiments of the Royal Commission on Rivers Pollution show that arsenic is removed from such waste liquors by filtration. How great would be the individual gain of manufacturers if, instead of having to depend on water companies for a supply of water at a large annual outlay, they were to adopt this plan of purifying their water before turning it into the river, whence all of them would then be able to derive an unfailing supply of pure water without cost. If the manufacturer at the head of the stream were to set the example, and his neighbors below would follow it, the river would be passed on from each to the other in a pure state, instead of in so foul a condition that the lowest manufactories are unable to use it.

But in the case of mines, the benefits to be derived from such a course are more apparent. The simple use of settling-pits, in which the mine-water is allowed to rest till the solid impurities subside, is sufficient to remove all the solid matters, so that the effluent water may be safely poured into the river. The mud or slime thus separated should be removed every day, and may be profitably utilized in the following manner, described by Mr. Frank Buckland:—"As regards the debris and mud of crushed rock, I am happy to say that some economical use can be made of it. I am informed by Mr. George, superintendent of the Upper Severn, that in the Van mines the slime from the catch-pits is being made into bricks, by being mixed with sand and burnt. They make very good bricks, and are used on the premises. This idea is most valuable, and all lead mine owners should adopt it. I have myself made several bricks with debris of lead mines and Portland cement; Roman cement will do. I shall be glad to send samples of these bricks to any person who applies for them. I have been informed by the foreman of the new works at the Old Windsor Lock on the Thames that the cement which sets best under water is Burham Company cement. The proportions for water work are one cement to four of washed gravel or refuse from lead mines; for other work one cement to eight or ten of washed gravel or lead refuse; this composition sets like solid rock." Not only can bricks be made of mud, but in some cases a considerable quantity of ore may be saved from it, which would otherwise be wasted.

The solid matters in the washings from China clay works, which do so much injury to the rivers of Devonshire and Cornwall, as well as the debris from mines, can be utilized by making bricks. But when the refuse cannot be made use of, it is desirable that "catch-pits," or settling-pits, should be made to receive the waste water from all such works. The Pollution Commissioners testify that settling-pits are capable of extracting in some cases a portion even of chemical impurities, but the solid matters can be easily removed by this means at no expense. The proper way is to have a double series of pits or tanks, large enough to hold a day's wash-water, so that the washings from one day can be subsiding in one set while the other set is being filled. This plan is most simple, and very efficacious.

The Devon Great Consolidated Mining Company employ the following simple plan for the extraction of copper in solution in waste mine-water, with most excellent results: The water is first passed through large filtering beds, to divest it of all earthy matter, and then conveyed over scrap-iron in a series of strips sufficient to throw the whole of the copper down. The iron is turned over and brushed during the day by a man in charge, to prevent it from becoming too thickly coated with copper when it would cease to be acted on. The copper is caught in a catch-pit at the end of each watercourse. The iron displaced by the action of the acid passes off in the form of ochre, which is caught in pits prepared for the purpose, and the water is again finally passed through a series of catch-pits and ponds before passing into the river.

The refuse from the tanyards is a fruitful source of pollution, but there is no reason why the rivers should receive this matter, which, if applied to the land, is a valuable manure. Why such a simple use for the waste water as turning it on the land as manure should so often remain ignored, we are puzzled to explain. The waste waters from other factories can also be utilized in this way after undergoing some simple processes. The dye-water from dye works can be purified in a very simple manner, and the refuse, after pouring off the clean water, used as manure. This liquor is, in its ordinary state, one of the most polluting of liquids, but it can be clarified by simple filtration through ashes or by precipitation. This latter process is hastened by the addition of lime. The dye-water is a solution of sulphate of iron, with insoluble dye matter in suspension. It should be turned into subsiding pits or tanks, when, on the addition of a little lime, the coloring matter is at once precipitated, and the superincumbent water is left clear. The proportion of lime is 10 lbs. to 1,000 gallons of water. By this means the water can be drained off comparatively pure and colorless, insted of going to foul the river and unfit its waters for use by manufacturers and others below.

Another mode of dealing with the refuse water from dye and print works is thus described by the Rivers Pollution Commission: "A form of mechanical filter, which has been found very valuable in several manufactures, early attracted our attention. It is a patent invention, known as Needham's press, consisting of a number of narrow chambers, lined with linen or calico, into which the liquid to be filtered is driven by a small force-pump. The liquid passes clear through the bags, while the solid portions are arrested. This action is maintained with low pressure until the chambers begin to be filled with solid residue, when it is necessary to increase the pressure. The machine is extensively used in the Potteries for the separation of clay from water in which it has been washed; it is also successfully adopted in paper-making, in breweries, and some other manufactures. The thin mixture of clay and water, known as 'slip,' was formerly dried on hot plates till it became fit for working. In many potteries the mixture is now pumped into Needham's machine under great pressure, and when the operation is complete the clay is taken out in solid cakes, which are strong enough to be readily handled and fit for the use of the potter.

"By the kindness of Mr. Henry Brooke, and under the superintendence and at the expense of Mr. Needham, one of these presses was fitted up in the dry-house at Bradley Mills, near Huddersfield, and experiments were made from day to day in the filtration of black dye. These trials were very satisfactory to us, as showing that it is perfectly practicable to separate from the dye-waste the most objectionable portion, and to discharge into the rivers a liquid comparatively pure. The machine actually employed at Bradley Mills, although only about 7 ft. square by 3 ft. in height, had a filtering area of 240 ft., and by it we were enabled to cleanse 700 to 1000 gallons of limed black dye-waste in an hour. The tank in which the dye-water was precipitated was capable of holding from 2,500 to 3,000 gallons, and was calculated for the treatment of from one to two days' discharge. Mr. Brooke considered that this tank and machine would enable him to purify all the dye refuse produced at his mill before discharge into the river. With regard to the solid material which is found in the cloths when the machine is taken to pieces, this substance is, as has been already explained, a combination of oxide of iron and vegetable matter. It is not difficult to dispose of it when taken from the press. It is similar to damp sawdust, and may be got rid of by mixing it with small coal, and burning it under the furnaces; better still is it to allow the material to dry up (which, from its light porous nature it readily does), and then to set fire to it; it burns like a slow match without flame, but so persistently that a heap once alight will burn till all the vegetable matter is consumed. There remains, after combustion, a red powder which is almost entirely oxide of iron. It forms from one-fifth to a quarter the weight of the black stuff, and would undoubtedly find a market, either to be made into red or chocolate paint for external ironwork, or to be used in the purification of gas, or for conversion into perchloride of iron for purposes of deodorization."

Waste water fron dye and print works, of all colors, may be treated in a similar way, and we feel assured that if a prohibition were at once to be placed on the pouring of such matters into our rivers, the ingenuity of our manufacturers would easily find some simple means of getting rid of it without injury, if not with direct profit to themselves.

STORAGE AND DISTRIBUTION OF WATER IN INDIA.*

By GEORGE GORDON, M. Inst. C. E.

It is not intended in this paper to discuss the value of water in its widest sense, or to consider the indirect benefits which would follow the control and abundant distribution of the enormous wealth of water now, for the most part, rolled into the sea—benefits among which are to be reckoned the prevention of famines and of scarcity in the districts concerned, as well as the permanent improvement of agriculture, and the numberless social and political advantages resulting from enhanced prosperity and increase of population. The object of this communication is rather to afford, from well-authenticated data, some means of estimating the more direct profits of works of irrigation which have been, or could be undertaken as commercial speculations in the present day. For this purpose some preliminary remarks on the works employed for storage and distribution, on the ancient and modern systems, seem needful.

TANK IRRIGATION.

The existing tank irrigation dates chiefly from ancient times. The number of tanks, large and small, in Southern India is enormous; some of them attain the dimensions of lakes, others suffice only for the irrigation of a few acres. They may be divided into three classes: 1st. Where advantage is taken of a narrow gorge in a range of hills, to close the passage of a river, by a dam or embankment of considerable height, and so to convert the valley above into a lake. 2d. Tanks formed by the construction of embankments across one or more streams in the flat country, this class being often of considerable superficial extent, but comparatively shallow. 3d. Such as may be considered intermediate between the first and second classes.

Most of the tanks of the first class are now ruined. In many cases the earthen embankment has been breached, in consequence of the water finding a passage along the outside of the discharge culvert, which was generally placed under the embankment, and not in a tunnel at a distance. The dams were, it is believed, invariably made of earth, without any puddle core, and the inner slope was always protected with heavy stone pitching.

The Author is not aware that high masonry dams were ever constructed for storage purposes in Southern India; but there is, near Ahmednuggur, in the Bombay Presidency, an instance of the combined use of masonry and earth, in a dam for a large ancient tank, described by Colonel Fife, R. E., in the Roorkee Papers. This dam, however, was never finished.

The number of disused tanks, of all sizes, is very remarkable. Many of these are not breached, but the discharge culvert is left open, and no water is collected. In many cases this is, probably, owing to the bed of the tank having been gradually raised by silting, and converted into so productive a soil, that it yields as much as, or more than, could be obtained by means of the diminished quantity of water applied to the comparatively barren soil below the tank; but generally it results from the ascertained fact, that the rainfall in some districts has

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* Abstract from the Minutes of the Procedings of the Institution of Civil Engineers.

materially diminished (markedly so even within the memory of man), on which account the tanks would never fill, and in most years would receive so small, and especially so uncertain a supply, as to render wet cultivation to any large extent not to be depended on. Dozens of such abandoned tanks are met with in the hilly parts of the Ceded Districts; as, for instance, along the foot of the inner slope of the Eastern Ghats, where, in many cases, both the bed of the tank and the cultivated land below it have reverted to jungle.

A good specimen of the tanks of the first kind is one which the Author was deputed to examine a few years ago, with a view to its restoration. A short description of it will afford an idea, both of the construction of ancient works and of the untrustworthy nature of the data which old works seem to afford for the construction of new works.

The Mudduk Masoor Tank is believed to have been constructed under the Annagoondy dynasty, about four centuries ago. It was formed by an embankment, resting on the sides of a narrow gorge through which the river Choardy passed, supplemented by two bunds, or dams, on saddles in the range of hills; that on the east being 1,350 yards, and that on the west 670 yards from the main bund. The length of the main bund is 550 yards on the top. The inside slope, of 2½ to 1, in some parts 3 to 1, was revetted with large stones, up to a cubic yard in bulk. It is from 945 to 1,100 ft. broad at the base, and is now from 91 to 108 ft. high. There was a sluice under the dam at the east end about the level of the ground. The dam is composed of a strong red earth, with a considerable admixture of gravel, taken from the sides of the hills on which it rests. The east supplemental bund has its base 74 ft. above the sluice in the main bund, and had also a sluice under it at the ground level. The west supplemental bund, the breaching of which destroyed the tank, seems to have been of similar construction to the others, and its base was perhaps 50 or 60 ft. above the bed of the tank. There is no trace of any waste-weir, and it is probable that the want of this was the cause of the ruin of the tank. On the main bund there are what seem to be traces of the water having topped it, and having cut into the rear slope in two deep gullies. The west bund had, probably, a sluice in it which weakened it, as cut stones were found in the river some way down. After this bund was breached, the water cut into the ground on which it stood to the depth of 100 ft., and would have completely emptied the tank but for a reef of rock some distance from the dam, on the inner side, which now causes a waterfall 25 to 30 ft. in height, and retains about 10 ft. of water in the tank. On this reef a weir has been built.

From the heights of the dams and the levels of the sluices, it is probable that the depth of the tank was 90 or 95 ft., and at that level its area would have been 40 square miles, and its contents about 1,400 million cubic yards of water. The drainage basin is about 500 square miles, and three-fourths of it lies within the jungly district containing the spurs of the Western Ghats. It is found, from observations of the discharge of the river, that a good average monsoon supply would not exceed 668,000,000 cubic yards, or 16 in. running off. It is not probable that the average annual rainfall so near the Western Ghats has diminished much, although it may, to some extent, from land having been cleared of jungle; nor is there anything to show that the ancient tank filled every year. The difference between the present supply, and what it must be supposed to have been when the tank filled and was breached (even supposing that to have occurred in an exceptional year), is probably owing, in part, to the construction of small tanks on some of the feeders. The tank, as proposed to be restored, would have contained about 644,000,000 cubic yards; and the results are given subsequently. As regards capacity, this is the largest reservoir in Southern India of which the Author can find any record.

Flat-country Tanks are so numerous in some districts that, looking at a map, it would appear as if as much land is occupied by tanks as is left to be irrigated by them; and where the tanks are very shallow, this would be necessary for complete irrigation. But in reality, many of these tanks are breached or abandoned, and their beds cultivated. The embankments of flat-country tanks are often of great length, not unusually 1 mile or 2 miles, while that of the Veeranum tank is 12 miles, and the ruined bank of the Poonairy tank, in the Trichinopoly district, is said to be 30 miles in length. Their height is generally inconsiderable, being, in many hundreds of cases, only sufficient to hold 10 ft., or even 6 ft. of water. Some works, however, of this, or of the intermediate class already mentioned, are (or were) 20, 40, and even 60 ft. deep. The inner side is generally revetted with stone, and has a slope sometimes of 1 to 1, but oftener of 2 to 1, or more. In some cases it is a masonry wall backed with earth. Clay puddle is not used in forming the banks, but the best earth in the immediate neighborhood is employed, and the dimensions are made large and sometimes excessive. The height above the water-level varies; for instance, the Nundyal tank bund is, at one place, 18 ft. high, 2 ft. above the water-level, 16 ft. wide on the top, with an inside slope of 1 to 1 and an outside slope of 2½ to 1. The Kolevoy tank in the Nellore district has a bank 36 ft. high, 9 ft. above the water-level, a top width of 12 ft., and slopes, inside and outside, of 1½ to 1.

Of Tanks of the Third, or Intermediate Class, the Darojee tank, in the Bellary district, is a good example. The embankment is about 2 miles in length, and rests on two rocky hills, two small hillocks being also included in the line of the bank. The area, when full, is about 2¼ square miles. Its height is about 40 ft., the depth of water being 26 ft. at the level of the waste-weir. This is of modern construction, and 400 ft. long, the old native one having been breached. The contents of this tank are roughly estimated at 25,000,000 cubic yards.

As the smaller streams in Southern India are merely torrents which quickly carry off heavy falls of rain and then become dry again, their powers of supply being reckoned by hours at a time rather than by weeks or months, they are, if utilized for irrigation at all, in most cases intercepted by chains of tanks of the second or third class built across their course. Therefore it is only the more important rivers that can supply means of extensive irrigation by channels diverted from them, and it is believed that all of these rivers were, to some extent, laid under contribution in former times.

Naturally their deltas formed the best ground for irrigation, and, consequently, the Godavery and the Kristna deltas, and the lands in the lower parts of the course of the Pennair, Palar, Cauvery, etc., have been, to a large extent, irrigated for ages, and the works have been much extended and improved by the British Government. It is chiefly from these exceptionally favored districts that the wonderful—and in some cases almost incredible—results of channel irrigation have been obtained. As descriptions of many of these works are accessible to the members, it seems unnecessary to occupy time in giving any account of them in this Paper, further than to say that, with one important exception, the conditions under which they were constructed are as favorable as they could be, viz., ground sloping moderately towards the sea and from the river—the source of supply, so that distribution of the water commences almost immediately; the absence of deep or hard cuttings in the canals; and, in the case of the modern improvements, the presence of a considerable population accustomed to the construction of such works and alive to the advantage of their extension. The one disadvantage referred to is the difficulty of constructing and maintaining weirs across the wide sandy beds of the rivers. This was beyond the skill of the native constructors. Very interesting accounts of some of these works will be found in the Professional Papers of the Madras Engineers, and in the Government records in the Library of the Institution.

But it is not only in the deltas that the rivers are tapped. In the middle reaches of the large rivers also there are many ancient weirs, generally admirably situated, but of rude and imperfect construction, so that many are ruined and others require extensive annual repairs. Advantage was usually taken of a reef of rocks running across the river, the low places being filled in with rubble, faced on both sides with large blocks of stone laid dry, occasionally fastened together. There is some leakage through the body of these native weirs, but not sufficient to account for the fact that, although they are not provided with scouring sluices, the bed of the river on the upper side of them has in several cases not been raised, as is the case where weirs have lately been built with scouring sluices at one end or both.

Where new weirs have been built on rock, they are generally of masonry, with a vertical or slightly battering face on the lower side. It is frequently necessary to protect the rock from the action of the falling water by a water cushion, formed by a low wall built a short way below the weir. The Author has seen a block weighing several tons picked out of what seemed, before the weir was built, a solid bed of gneiss with no visible seams; the height to the crest of the weir was, speaking from memory, not more then 7 ft., and there may have been 5 or 6 ft. going over the crest. The Author knows of no rule for determining the depth of the water cushion, by the height of the fall and the volume of the water. The greatest depth of the hole formed by the water-fall in the new outlet of the Mudduk Masoor tank is 24 ft. At the low state of the river, the height of the lip of the fall is 27½ ft. above the surface of the water below. In ordinary states of the river, the general depth of the cushion, or well, is to the height of the fall as 3 to 4 where the greatest action takes place, and 1 to 2 in the other places. At the Gairsoppa Falls, in the Western Ghats, the Rajah fall, which through its whole height falls clear of the rock, is 825 ft. high, and the pool into which it falls is 138 ft. deep in the low state of the river. Perhaps 8 ft. on the edge of the fall would be the depth in floods, and then the surface of the cauldron below, if it could be said to have one, would be raised many feet; it would be impossible to measure it. An experimental fall on the Baree Doab canal had a height of 6.9 ft., depth of well 9 ft., and 3.6 ft. on the crest, which gives the depth of the well to the height of the fall as 3 to 4; and it is said the water had no injurious effect on the bottom of the well, and that a bottle, loaded so as to be of the same specific gravity as the water, and passed over the fall, did not reach the bottom by a foot and a half.

In sandy-bedded rivers, the modern practice is to build the weir on a foundation of wells filled with concrete, to give it an apron sloping about 1 in 12 from the crest, with a toe wall, and if the slope is long, one or more intermediate walls, also built on wells, and below all a broad layer of rough rubble of large dimensions. A good example of this kind is the Madras Irrigation Company's weir across the Pennair, near Cuddapah, of which a description will will be given to the Institution by Mr. Higginson, M. Inst. C. E.

All the ancient irrigation channels from above weirs, that have come under the Author's notice, have far too great a fall, and consequently cannot get away from the river, and thus only a narrow strip of land is irrigated; the sides and bed of the channel get cut away in some places, and the material deposited in others, so that annual repairs and clearing out are necessary. There is also invariably a great waste of water in distribution; but as the surplus runs into the river it is not lost, being picked up again at the next weir. The tail of one channel generally overlaps the head of the next for some distance in the native system. There can be little doubt that this system of numerous weirs and small channels, with a rapid fall, is radically wrong, when applied to large rivers for extensive irrigation. On smaller rivers, having a steep fall, say of 10 ft. or more per mile, rocky beds, and widths so moderate as to make the cost of the weir a small part of the whole work, it may sometimes be well applied—the more so as in such situations the soil is likely to be of a light and porous nature, requiring a large quantity of water to be spread over it, and delivering the surplus by drainage into the river again. Generally speaking, however, in the case of large rivers it will be found more economical to take off a canal of larger dimensions from one head. The surface fall of the water can then be much less than in a channel the depth of which is small; the canal will rapidly recede from the river bank, and command, compared to its length, a much larger area of land; it will wind less, as it will cross the drainage valleys higher up, where they are less deep; these drainages will require less expensive aqueducts and approaches; there will be a shorter length of unproductive canal at the head (from the off-take to where the canal level is high enough to deliver water on to the surface of the ground), and it will supply water to lands and villages where it is more urgently needed than it is close along the banks of a river. Careful estimates, however, are needed, in each case, of considerations on the other side. For instance, the canal must not be made of so large a capacity that a great part of the water must be carried very many miles before it can be used. The cost of distribution, too, must be considered. Although the natural channels of streams can often be used to convey part of the water to the fields, it is generally the case that, for extensive irrigation, artificial channels, carried down the ridges crossed by the canal, are more economical; but they must not be too long.

It is desirable that a main canal should command a much greater area of arable land than the water it carries can irrigate constantly. Some land may not be suitable for irrigation at all; and in no case could all the land be converted from dry to wet cultivation under many years, as three times the population would be required to cultivate it. There should, therefore, be facilities for completely irrigating detached areas at considerable intervals, and for giving occasional irrigation to dry crops. This last would be an immense boon, since in many parts complete failure of the crops now grown happens every few years from drought, and a good crop is a rare exception; while from one to three waterings would insure a good crop every year. A failure of the crop means a famine; and although, in the few districts traversed by railways, food and seed grain for next year could, at a great cost, be provided for the people, fodder, and, above all water for the cattle, could not, and they must be driven away or perish. At one large military station, so great was the scarcity of water in the early part of the year 1871, that arrangements were actually completed for carrying water a distance of 8 miles on railway-trucks for the use of the inhabitants. As to drink water thus provided would be contrary to the religious obligations of caste-men, their dismay was great. Fortunately, a heavy rain furnished a supply for two or three months.

The large storage tanks already described as of the first class do not have more than a limited area of land irrigated immediately from them. Their duty is to store flood-water which would otherwise run to waste, and to let it down the river as it is required, to supplement, if necessary, at the end of the season, the regular monsoon supply for the first crop, or to give a supply for a second, and to be distributed either by channel irrigation from the river, or from the flat-country tanks, if it is used to supply them. From the second and third class of tanks the distribution is generally effected directly, beginning close under the tank, the water being let out on to the land by sluices at different levels. In some cases, however, as in that of the Darojee tank already mentioned, the water is also carried down the beds of the intercepted streams and picked up by weirs put across them at intervals; but this is the less frequent plan. One advantage of it is, that the drainage and also the superfluous water from the fields, for it is always wastefully used, are not lost.

Distribution from a canal is most economically effected when the latter runs along a ridge between two valleys, so that it can supply water on both sides; for the nearer the irrigated land lies to the supply the less do the distribution channels cost. This situation, in the case of a large canal taken from one of the main drainages of the country, can obviously happen only in rare instances. When the main canal is carried along sidelong ground crossing the drainage of the country, the main irrigating channels will generally be carried down the ridges between the streams, giving off secondary branches right and left. Occasionally, when the main canal passes by a cutting through a ridge crossing its course, a channel on a falling contour will be required on the upper, and another on the lower slope of such ridge, uniting when the crest of the ridge falls to their level. The first kind, or ridge channels, have the advantage of crossing no drainage, of being thus less liable to damage from heavy rains, and of commanding a given area with the least length of side channels. In most cases both kind of channels will be needed. In the Ceded Districts, distribution can be carried out for 5s. per acre, including the sluices in the main canal bank, and all necessary works for crossing roads and streams built in a permanent manner, but excluding the cost of terracing the land to prepare it for wet cultivation,—this being done by the occupier.

Of course, any system of irrigation must include ample means of drainage. This is afforded naturally in the part of India under consideration, the fall of the country being generally steeper than is necessary. Only surface drainage is practised. For rice cultivation the water must not be carried off too rapidly, but should be retained for months at a depth of 6 in. on the surface of the ground, by surrounding the plots with a small bank, through which a slight stream is allowed to pass on and off. For dry crops the ground never holds too much rain; the more careful cultivators endeavor to retain, by small dams of dry rubble or boulders, the finer parts of the soil, which would otherwise be carried of by the very heavy rains; but, except in irrigated lands, drains are never cut, as far as the Author is aware.*

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* Only so much of Mr. Gordon's paper is produced here as seemed to contain valuable suggestions to American Engineers. At this point detailed estimates of cost and of values for Indian crops are omitted.

GENERAL CONCLUSIONS.

As there seems to exist a general impression, that the estimates of the benefits of irrigation are merely estimates, more or less colored by personal views, the author has, in the statements of the comparative results of wet and dry cultivation, confined himself to ascertained facts, and has endeavored to keep the estimates of returns on works within the limits of certainty by excluding all doubtful or unascertainable profits, such as those from plantations for firewood (a very profitable investment where the earth can be kept sufficiently moist), water supplied to towns and villages for domestic and municipal purposes, water-power, etc. Also, he has taken as the standard of productiveness that of irrigation under tanks, and has not added the 25 per cent. additional crop said to be due to channel irrigation.

As this paper is intended to deal with works for irrigation only, navigation is not included in either the cost or the returns; but the Author begs leave to make one or two remarks on this subject, on which so much opposition exists in the views of engineers. This opposition he believes arises from each side attempting to form general conclusions, and to lay down a general rule founded on the observation of particular works, which in each case seem to bear out its advocate's views. The question does not admit of a general answer, either in favor of or adverse to the combination of irrigation and of navigation in one channel. Assuming that a navigable canal is desirable, if it can be constructed at a small outlay, the question whether an irrigation canal should be adapted to that use or not seems to depend for its solution mainly on two circumstances: first, the nature of the ground through which it passes; and, secondly, on its dimensions. If the former is such that a rapid current can be given to the water, it is very desirable to do so in cuttings, in order to reduce their cross section, and this generally to such an extent as would prevent upward navigation. If, on the other hand, the country is very level, as in deltas, and the soil so light that the velocity of the canal has to be small, then the addition of works required for navigation bears so small a proportion to the whole outlay, that to make the irrigation canal navigable is the cheapest way of attaining the end. Thus, in the Orissa scheme, the cost of the navigation works is said to be about one-eighth of the whole cost; and a complete network of navigable lines is obtained at an outlay of £650 per mile. In a less easy country the Author has found that when a canal has to carry from 150,000 to 500,000 cubic yards per hour, and when it has to pass through cuttings, it would be cheaper to have a separate navigation taken round, or in some other way avoiding the difficult parts, than so to enlarge the irrigation canal as to reduce its current within navigable limits. But when a canal has tapered down to 150,000 or 100,000 cubic yards per hour, then it is cheaper to combine irrigation with navigation in one canal. In a tract of country comprising both characters of ground, it was found that to combine a system of navigation with irrigation would add 25 per cent. to the cost of the latter, and would cost from £2,000 to £3,000 per mile, according to the dimensions of the work; but in difficult ground, if the canal were of large dimensions, carrying 450,000 cubic yards per hour, £6,000 per mile would be required to make it navigable. The parts of the canal used for navigation only would cost £1,200 or £1,500 per mile, exclusive of the locks, which, if 100 ft. long and 20 ft. wide, would cost about £200 per foot of lift. These rates per mile suppose a supply derived from the canal, and do not include headworks or storage reservoirs, as these works are supposed to be charged to irrigation, inasmuch as the water used for lockage would also be expended in the fields.

In the above estimates no account has been taken of the value of the land occupied by the works. It has generally a low value in such districts as require irrigation. In the Orissa system of works it cost 1.8 per cent. of the capital expended; and in any case it becomes quite insignificant, when compared with the indirect advantages accruing to Government from the improvement of the country by irrigation. The most obvious of these is the saving of remissions of land revenue, which have often to be made in consequence of partial or total failure of crops. There is also the relief from uncertainty in the amount of the revenue. In the irrigated districts of Tanjore, the fluctuations in the revenue have declined since the construction of the Government irrigation works from 52 per cent. to 3 or 4 per cent. Other sources of gain to the State are—waste lands brought under cultivation, and so under a charge for rent; increase of the customs and taxation in general; and a large saving of money relief in times of famine. These gains cannot be estimated, and no account has been taken of them in the above calculations, except as a set-off against the value of the land.

No special notice has been taken in this Paper of the great and very remunerative works in the Kristna, Godavery, and Tanjore deltas, the works in the last yielding, according to an independent authority, after deducting repairs and 5 per cent. on the capital, $23\frac{1}{2}$ per cent. direct profits, and those on the Godavery from 50 to 60 per cent. They are omitted because these deltas are so occupied as to offer no opportunity of constructing new works on a large scale.

Persons unacquainted with the native character will be apt to ask why, if irrigation works are so profitable, the natives have not already utilized every drop of available water; but this will be no ground of wonder to those who know their ignorance of the practice of any but their own neighborhood, their worship of custom, and their habit of relying on their rulers to do everything for them. In the Godavery districts, on the completion of the works, the Government officers are said to have acted in a paternal manner to the ryots by turning the water on to their fields, with or without their consent, and they have been rewarded by the unexampled prosperity of the district.

The object of this Paper will have been attained if it has shown:

First.—That all works of irrigation benefit the cultivator to such an extent as will enable him to pay a water-rate equal to two-thirds of the increased value of his crop, and not exceeding one-half the net value, and still to leave his own profits by 100 to 400 per cent. in excess of those derived from dry cultivation.

Secondly.—The storage of water for the raising of a second crop, under distribution works already in existence, is the most profitable, and would, after paying one-third of the gross revenue to the existing works, still yield a net return of 46 per cent. on the outlay, and increase the revenue of the existing works, supposing them to have cost the average sum, by $4\frac{1}{4}$ per cent.

Thirdly.—That the arbitrary rate of 12s. per acre is insufficient, on the data assumed by the Government, to yield a fair return directly on the average of new irrigation works, unless these include the storage of water, when the Government rate will yield a net profit, on storage and distribution works combined, of 10 per cent.

And *Fourthly.*—That as a consequence of the last, the profitable employment of unguaranteed capital in irrigation works depends chiefly on the recognition of the principle, that the water-rate should be fixed with reference to the value of the crop produced. This value will, in all probability, continue to increase, as will also the cost of the works as wages increase; and unless the water-rate is fixed with due regard to the value of the water to the consumers, and to the cost of work in each district, many beneficial projects will remain unexecuted.

(To be continued.)

THEORY OF THE GIFFARD INJECTOR.

Translated from "Sonnet's Dictionnaire dès Mathematiques Appliquées."

To establish the complete and rigorous theory of this apparatus would be very difficult. Mr. Giffard in his "Notice Théorique de l'Injecteur Automatique" (1861), has given an approximate theory founded upon the doctrine of the conservation of the *quantity of motion.*

Let p = the weight of the liquid which escapes in one second from the orifice of the tuyere.
P = the weight of water moved by suction.
m and M = the corresponding masses.
ω the section of the orifice of the tuyere.
V = the velocity of the steam at this point.
v = the velocity of the water at this point.
a = the minimum section ($m\ m$) of the divergent tube.

Let us consider the portion of fluid in motion between two sections near the end of the spindle, and near the small end of the diverging tube. At the end of a very short time θ the molecules which were in one section will be transferred to the other. Because of the conservation of motion the quantity of motion of the portion of fluid comprised between the sections will be constant; hence the increase of the quantity of motion of the fluid between the above specified sections is reduced to

$$(m+\mathrm{M})\,\theta\, v-m\,\theta\,\mathrm{V}.$$

Let R be the sum of the projections upon the axis of motion of the exterior forces acting on the fluid; then by virtue of the principle of the quantity of motion

$$(m+\mathrm{M})\,\theta v-m\theta\,\mathrm{V}=\mathrm{R}\,\theta$$

or

$$(m+\mathrm{M})\,v-m\,\mathrm{V}=\mathrm{R}.$$

Neglecting friction, and assuming that the resultants of the pressures in the two directions are equal, R = 0, and

$$(m+\mathrm{M})\,v-m\,\mathrm{V}=0,$$

or, substituting weights for masses

$$(\mathrm{P}+p)\,v-p\,\mathrm{V}=0 \quad . \quad . \quad (1.)$$

$$\therefore p=(\mathrm{P}+p)\frac{v}{\mathrm{V}} \quad . \quad . \quad (2.)$$

The sum $\mathrm{P}+p$ is generally given; it is the weight of the water to be introduced into the boiler in a second of time; and it is equal to the weight of steam to be generated by the boiler according to its heating surface, increased by about 40 to 100 per cent. in order to take into account the water mechanically moved. The velocities v and V are not directly given. Mr. Giffard considers that the fluid escapes with the same density. Let δ represent this density, or rather the weight of a cubic metre of steam, and n the number of atmospheres pressure in the boiler, diminished by unity; since the pressure about the fluid vein may be regarded as equal to the atmospheric pressure: then

$$\mathrm{V}=\sqrt{2\,g\frac{10334\,n}{\delta}} \qquad (3.)$$

Let W = the weight of a cubic metre of the liquid flowing into the divergent tube. In order that this may be introduced into the boiler, the *vis viva* must be equal to the negative work of the pressure, which opposes this introduction; *i. e.*

$$v=\sqrt{2\,g\mathrm{H}}$$

H being the height of fluid to which the pressure is due. But experience shows that at the mouth of the divergent tube the liquid, still mingled with air and steam not condensed, has a density much less than that of water; on the other hand, in taking into account the friction in the divergent tube, it is necessary to give the liquid an excess of velocity. In view of this, Giffard proposes the following formula

$$\mathrm{V}=\sqrt{2\,g\,k\frac{10334\,n}{1000}} \quad . \quad . \quad (4.)$$

k being a coefficient between 2 and 2.25, as determined by experiment.

Further, we have

$$p=\omega\,\mathrm{V}\,d \quad . \quad . \quad . \quad (5.)$$

and

$$\mathrm{P}+p=a\,v\,\mathrm{W}.$$

W being the weight of a cubic metre of liquid in the divergent tube, *i. e.*, about 500 kil. Formulas (2), (3), (4), (5), (6), contain the solution of the problem.

Equations (3) and (4) give the velocities V and v; (2) determines the weight p; (5) and (6) give the sections ω and a.

The temperature of the feed water is easily derived from the values of P and p. Let T represent the temperature of the steam at departure from the feed pipe and τ that of the mixture which flows into the divergent tube. The quantity of heat lost by the steam in passing from the temperature T to τ is according to Regnault

$$p\,(606.5+0.305\,\mathrm{T}-t)$$

and the quantity of heat gained by the water passing from the temperature t to τ is $\mathrm{P}\,(\tau-t)$.

The loss being equal to the gain,

$$p\,(606.5+0.305\,\mathrm{T}-\tau)=\mathrm{P}\,(\tau-t)$$

$$\therefore \tau=\frac{p\,(606.5+0.305\,\mathrm{T})+p\,t}{\mathrm{P}+p}$$

The temperature T is not exactly known; but we may suppose it equal at least to 100°; and from it we can hence deduce the minimum of temperature of mixture.

Suppose, for example, a boiler in which the steam is generated at a pressure of 6 atm., with a heated surface of 20 c. m. Allowing a mean generation of 20 k. of steam per square metre hourly, we have a product of 400 k. Add about 40 per cent. for water set in motion, and we have 560 k. per hour, or 0.155555 c. m. per second. In this case

$$\mathrm{P}+p=0.156\ \text{kil.}$$

nearly

$$n=5$$

Density at 6 atm. (160°.2)=0.003

∴ δ = weight of cubic metre = 3 kil.

Hence

$$V = \sqrt{2\,g \,.\, \frac{10334.5}{3}} = 581.3 \text{ m.}$$

$$v = \sqrt{2\,g \,.\, 2.25\, \frac{10334.5}{1000}} = 47.8 \text{ m.}$$

Hence

$$p = 0.156 \times \frac{47.8}{581.3} = 0.0128 \text{ k.}$$

Formulas (5) and (6) give

$$\omega = 7.34 \text{ sq. met.}$$
$$a = 6.53 \text{ sq. met.}$$

Corresponding to diameters of 3 and 2.5 mm.

Supposing the water in the reservoir at 12° and T = 100°.

$$\tau = 12° + 0.082\ (637-12) = 63°.25,$$

the minimum of temperature for feed water.

NEW MODE OF HARDENING STEEL AND REGENERATION OF BURNT IRON.

By Lieutenant-Colonel H. Caron.

From "Iron."

A piece of steel is first hardened, then softened more or less, according to the hardness or elasticity desired. The hardening, as it is ordinarily practised, that is to say, the hardening of the red-hot metal in cold water, frequently has the grave inconvenience of developing rents and cracks disadvantageous to the powers of resistance of the metal. The process of softening then gone through does not cause these defects to disappear; later, in the using, these fissures, invisible at first, increase little by little, and finally end in a serious rupture. It is already well known that to obviate in part such a danger, it is better to make the steel less hard, and soften it more lightly. A spring heated red-hot, hardened in cold water and softened with burning oil, possesses the same elasticity as a similar spring hardened with cold oil (a weaker hardening than the first) and softened with "smoking" oil (a lesser softening than the preceding); only the latter method is more advantageous, because there is less fear of cracks from a too rapid cooling of the metal. Wishing to go farther, I asked myself if it were really necessary to commence by hardening the steel beyond measure, just to reverse the process and soften it by a second operation. With this in view I have sought a hardening of such mildness as to remove as much as possible the chances of cracks, and produce in the steel, at a single operation, the effects of hardening and softening combined.

I have found a very simple method, namely, by warming the water into which the red-hot metal is to be thrown. After ome experiments a temperature of about 5 deg. was found to be sufficient to give to the above-mentioned springs (springs of needle-guns) an elasticity and resistance equal to that produced by the best hardened followed by an after softening. Necessarily the temperature must vary with the size of the piece and the uses to which it is destined. The degree of warmth of the bath is easy to determine by trying it beforehand.

Hardening with very hot water, and better still, boiling, singularly modifies soft steel containing .002 to .004 of carbon. It increases its tenacity and elasticity without materially altering its softness; the grain changes in nature, and often where there is a breach it is found to have become fibrous instead of granular or crystalline, as it was before.

In a communication inserted in the Report of the Academy of Science last year, I have demonstrated that the crystalline texture presented by the fracture of certain pieces of iron is neither due to the action of the cold nor to that of prolonged vibration, but that it existed in the metal previous to its being used. After my experience, that particular formation I found to result from an incomplete forging, leaving the metal still "burnt," *i. e.*, crystalline and full of cracks. I said, besides, that it was possible to give the iron thus deteriorated the fibrous texture or the tenacity which it would have had if the operations of the forge had been well gone through, and that, without having recourse, as was formerly done, to a new hammering, which results in a loss of time, of metal, and often in the wasting of the piece itself. The means which I employ to regenerate burn-iron is like that of hardening red-hot metal in warm water. I shall cite but one example to prove this.

A bar of Berry iron, three centimetres in diameter, easy to break, without a crack, cleft, or flaw, was burnt, *i. e.*, warmed in such a manner that, pressed in a screw-vice, it could be broken without bending. The fracture was strewn with brilliant facets of many thousand squares. A boiling liquid, strongly impregnated with ordinary salt, was prepared; a piece of the burnt iron, heated red-hot, was plunged in this liquid, during the time necessary to bring the metal to the temperature of the bath (about 110 deg.). It immediately produced a rather curious phenomenon; directly it was plunged in the salt solution the red metal was covered with white salt, which detached it from the water, and certainly contributed to diminish its cooling. The piece of iron thus hardened was capable of being bent back upon itself, as the bar had been before being burnt. Pure water, boiling, can be employed as well, but its effects are less marked.

Now it is known that boiling salt-water can regenerate burnt iron, it will be to the interest of the manufacturer to apply this operation to pieces after being finished at the forge, as the hardening will not damage them at all; if, on the contrary, they have suffered from too much or too prolonged heat, it will give them the qualities which a good forging imparts. Just the same applies to steel.

It is likely that there may be other liquids and other solutions which would produce the same results as the saline solution, but I have only mentioned this one because it appears to me to be the most economical and the most easily procured at the same time.

REPORTS OF ENGINEERS' SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—At the evening meeting of the Society to be held Wednesday, January 21st, "Test of materials used in construction, and testing machines" will be considered; reference is made to the Report of the Committee on "Tests of American iron and steel," and the remarks offered at the meeting held November 17th last, herewith published; members having information upon the subject are requested to present it; full descriptions of testing machines in use are specially asked for.

At the evening meeting of the Society to be held Wednesday, February 18th, an examination into "The elements of cost of railroad traffic" will be made, with a view to determine the same under their appropriate heads, and to discover wherein, and in what manner, a reduction may be effected. The discussion upon LXII Transactions, herewith published, bears upon this subject, which it is hoped railroad managers and others interested will take up and continue. Details of the several items of cost of railroad traffic, as given in reports or otherwise, and references to where such may be found, are desired.

IRON AND STEEL NOTES.

IMPROVEMENT IN HARDENING THE SURFACES OF IRON. — Specification forming part of Letters Patent issued to Robert T. King, of Pana, Ill.

The object of this invention is to furnish a suitable compound for case-hardening iron, or converting the surface into steel; and it consists in a combination of various ingredients or substances, which form the composition hereinafter mentioned, and used in about the proportions named, for forming the compound, viz.: Lamp-black, sixteen parts; sal-soda, eight parts; muriate of soda, four parts; black oxide of manganese, one part.

These substances are combined in the above proportions (by weight), and are finely powdered.

The iron is heated in any suitable forge or furnace, and, having been wrought into the shape of the implement or article to be used, and the surface thereof prepared by grinding, the compound is applied by sprinkling or sifting, or by immersing the iron therein. The effect is to carbonize and steelify the surface of the iron to a greater or less extent.

A thinner or thicker scale of steel is formed by varying the quantity of the compound applied or the temperature of the iron to be case-hardened.

Claim.—The above described compound, substantially as and for the purposes herein shown and described.—*Iron Age.*

IMPROVEMENT IN WELDING IRON AND STEEL.—Specification forming part of Letters Patent issued to Joseph Popping, of New York.

This invention is in the nature of an improvement in the process of welding iron and steel; and the invention consists in applying between the surfaces to be welded a compound of borax, iron filings, and prussiate of potassa, and subjecting the iron to a red heat and pressure or percussion, and thereby welding the same.

As is well known, in welding iron it has been necessary to heat the pieces to be welded together to a white heat, and that while this process of welding answers for welding iron, it does not, without great care and danger of destroying the steel, answer for welding steel to steel or steel to iron, for the reason that the white heat required does, in many instances, destroy the steel. Hence, more or less difficulty has always attended the welding of iron and steel together.

By this invention iron is welded to steel and iron to iron without difficulty. The surface of the metal it is designed to weld is moistened with water, and on the wet surface is sprinkled a compound consisting of 1 lb. of pulverized calcined borax, 1 lb. of fine iron filings, and 4 oz. of pulverized prussiate of potassa, intimately mixed together, the moistened surfaces of the iron causing the above compound to adhere to them. The two surfaces to be welded are then placed together and wired, or otherwise held in place, and put into a fire and brought up to a red heat, or to a temperature of 600 or 700 deg. Fahrenheit. The red-hot metal may then be passed between rolls or placed under a hammer, when the rolling or hammering will complete the process, forming a strong and perfect weld, the welded surfaces being intimately blended together. The prussiate of potassa may be calcined, which will facilitate the welding to some extent. The proportionate amount of the above ingredients may be varied more or less without particularly affecting the result.

Claim.—1. For welding purposes, a compound composed of calcined borax, iron filings, and prussiate of potassa, in the proportions, and applied in the manner, hereinbefore described.

2. The process, hereinbefore described, of welding iron and steel, viz., applying to the surfaces to be welded the compound named, joining the prepared surfaces of the metal together, heating them red-hot, and hammering or rolling the same.—*Iron Age.*

RAILWAY NOTES.

A Novel Locomotive.—There has just been completed at the machine-shop of Lafferty & Bros., Gloucester City, N. J., a four-ton locomotive, designed to run on one rail. It is built for a street railroad company in Georgia. This engine can with propriety be called a steam velocipede, as it rests upon two wheels, one following the other. The rail or track upon which it is to run, a sample of which is laid in the yard of the builders, is styled "Prismoid, or one track railway," and is composed of several thicknesses of plank, built up in the style of an inverted keel of a vessel, with a flat rail on the apex. Upon a trial a speed of about twelve miles an hour was attained, and the inventor and patentee claims that the speed can be almost doubled on a lengthened track. Mr. E. Crew, of Opelika, Ga., is the inventor and patentee of both tracks and engines, and he claims that his invention demonstrates a tractive power superior to anything in the locomotive line of equal weight. The capacity for running curves is very much greater than the tow-rail system. The track upon which the trial was made contained 36 ft. of lumber and 18 lbs. of iron to the lineal foot, proving itself equal to a span of 20 ft., remaining firm and unyielding under the pressure of the engine as it traversed the road. The revolving flanges attached to the engine, and which run on the outside of each wheel, Mr. Crew claims, absolutely lock the rolling stock to the prism, and obviate the necessity of so much heavy rolling stock in light traffic at a high rate of speed. It is also claimed that a prismoidal railway built with a base of fourteen inches, angles forty degrees, can be built at a cost of $3,000 per mile. The inventor is of opinion that this engine and track is particularly adapted to the propelling of canal boats, and will compete sucessfully with horsepower on canals without necessarily interfering with the use of the latter, but he does not state in what way. The engine will shortly be shipped to its destination (Atlanta, Ga.), where it goes into operation on a street railroad, built at an elevation of twelve feet above the sidewalk.—*Am. Manufacturer.*

The Work of 1873.—We give elsewhere an elaborate statement of the work done in constructing new railroads in 1873, which is, we believe, very nearly exact. We have attempted to describe in it the length and location of every railroad and part of a railroad constructed during the year with sufficient exactness to enable the reader to draw it roughly on the map.

STATE.	New road in		Per cent. of increase in 1873.	Total at close of 1873.
	1872.	1873.		
Alabama	134	0	0	1,566
Arkansas	156	247½	55	697
California	195	85	7	1,305
Colorado	105	121	25	604
Connecticut	25	29	3⅓	897
Dakota	210	80½	37	291
Delaware	26½	21½	8½	275
Florida	10½	0	0	466
Georgia	46	99	4⅔	2,259
Illinois	686½	253½	4	6,615
Indiana	183	65	1¾	3,714
Indian Territory	149	0	0	279
Iowa	452	93	2½	3,736
Kansas	445	36	1½	2,377
Kentucky	143	54	4¼	1,320
Louisiana	3	0	0	539
Maine	62½	0	0	871
Massachusetts	37	113½	7	1,772
Maryland and D. C.	190	34	3⅓	1,046
Michigan	571	182	6⅓	3,071
Minnesota	307	43½	2¼	1,950
Mississippi	22	7	0⅔	997
Missouri	314	236½	9	2,910
Nebraska	212	0	0	1,051
Nevada	18	18	3	629
New Hampshire	43	48	7½	858
New Jersey	103	40½	3	1,418
New York	435	242	5	5,417
North Carolina	60	15	1¼	1,265
Ohio	456½	131	3⅓	4,239
Oregon	82	10	4	251
Pennsylvania	251	191	3½	5,560
Rhode Island	0	22	16	158
South Carolina	88	88	6⅔	1,378
Tennessee	15	114	7⅓	1,634
Texas	391	485½	45	1,563
Utah	57	85	24	434
Vermont	31	53	7½	763
Virginia	49½	36	2⅓	1,573
Washington	40	40	60	105
West Virginia	76	36	6½	597
Wisconsin	459½	320½	17	2,198
Wyoming	0	0	0	459
Totals and average	7,340	3,777	5	70,857

There are many things which will be more apparent from the tabular statement given above than from the more elaborate account of the separate lines. This table gives the mileage of railroad completed in 1872 as well as in 1873, the percentage of increase of the last year, and the total at the close of the year. As authority for the mileage at the close of 1872 we have taken "Poor's Manual," which may be not always correct, but is doubtless the best statement we have. We have never made an attempt to ascertain exactly the mileage of each State existing at any given date, and therefore are unwilling to be responsible for the total mileage given.

The contrast between the first and second columns in this table is very striking, and especially in their totals. We built very little more than half as much railroad in 1873 as in 1872, and while the rate of increase for the whole country was 12¼ per cent. in 1872 it was only 5 per cent. last year. It should not be forgotten, however, that this is itself a very large increase. It makes the total completed in the United States since 1865 just about 35,800 miles, or more than half of the entire mileage of the country at this date was constructed within the last eight years.

The progress in the different States has been various, of course. Ten of them show a greater mileage than last year, including all the New England States except Maine, which is one of the seven States and Territories which have no new mileage, besides the four (Arizona, New Mexico, Montana and Idaho) which never have had any.

In the order of the amount of new road constructed in the year, those which have built more than 100 miles rank as follows: Texas, Wisconsin, Illinois, Arkansas, New York, Missouri, Pennsylvania, Michigan, Ohio, Colorado, Tennessee and Massachusetts. There are 265 miles of new railroad in New England, 595 in the old four "Middle States," 272 in the Southern Atlantic Coast States, from Maryland to Florida inclusive, only seven miles in all the Gulf States east of Texas, 733 in Texas and Arkansas (which may be called the West of the South, and almost its only new country), 168 miles in Tennessee and Kentucky, 995 in the six Western States which touch the great lakes, from Ohio to Minnesota, 446 in the States and Territories north of Arkansas west of the Mississippi and east of the Rockies (excluding Minnesota), 225 in the mountain Territories and States east of California, and 135 on the Pacific coast.

Texas, Arkansas, and Wisconsin have made really notable progress during the year, increasing by a very large percentage as well as a large mileage the railroad within their borders.

The decline of railroad construction began with the beginning, not the close, of the year. It was perhaps the first decided sympton of the financial difficulties which overwhelmed the country in September. An examination of our record will show that an unusually large part of the new work consisted in the *completion* of roads previously begun, and that, comparatively, not many of the new lines will need to be extended before they can be made available, though doubtless many of them require considerable expenditures to put them in anything like good order for traffic. Our rule regarding reporting the construction of a new road is to give it *when the rails are laid.* When this has been done the road is pretty sure to be worked for traffic.

As to the prospects for the current year, 1874, we have given our opinion frequently that there is likely to be a still smaller construction of *new lines.* Our railroads depend almost exclusively upon borrowed money—that is, scarcely any of them can be completed without *some* borrowed money—and investors are likely to be very slow for some time to come to lend money on the security of incomplete lines not yet earning any income. There is, however, a great need of extensive new works on old lines; these are likely to have good credit, and they may to a considerable extent make up for the decline in the building of new railroads.—*Railroad Gazette.*

ENGINEERING STRUCTURES.

BRIDGES IN FRANCE.—According to some recent statistics published by the Minister of Public Works, it appears that there are at the present time 1,982 bridges of importance in France, 861 of which were built previous to the nineteenth century, 64 during the First Empire, 180 during the Restoration, 580 in the reign of Louis Philippe, and 297 since 1848. With regard to the material of which they are constructed, 854 are of stone, 9 iron, 70 suspension bridges, 67 with masonry piers and wooden superstructures, 14 entirely of timber, and 20 of wood, iron, and masonry combined. 1,067 of these bridges are on national roads, 18 on roads for strategical purposes, 6 on fresh roads, and 891 on Departmental roads. Among the most important are the bridge of Bordeaux, commenced under the First Empire, 501 metres in length, consisting of 17 arches, and cost 6,850,000f.; the suspension bridge over the Dordogne at Cubzac, 545 metres in length, cost 2,200,000f.; the "Saint Esprit" bridge over the Rhone, commenced in 1265, consisting of 18 arches, is 738 metres in length, and cost not less than 4,500,000 francs; the bridge at Toulouse over the Garonne, cost 2,700,000f.; that at Libourne on the Dordogne, 4,236,948f.; the bridge at Tours over the Loire, 125 metres in length, consisting of 15 arches, cost 4,224,639f.; the "Pont de la Guillotine" over the Rhone at Lyons, commenced in 1245 with 8 arches, and 263 metres long, is estimated to have cost 2½ milliards; the Penfield swing bridge at Brest was constructed at a cost of 2,800,000f.; the Pont Neuf over the Seine at Paris, commenced in 1578, 231 metres in length, cost 4,000,000 francs; the Pont d'Jena, also at Paris, built under the First Empire at a cost of 6,135,105f.; the Pont de Roane, 232 metres in length, commenced in 1811, cost 6,438,561f. The total length of these bridges is estimated by the engineers of the "Ponts et Chausees" to be about 166 kilometres (about 100 English miles), and the cost of their construction 286,507,761f. (£11,460,310.)—*Building News.*

NEW HYDRAULIC BRIDGE AT LEITH.—The new hydraulic bridge connecting the Victoria and Albert Docks, and spanning the harbor near the Prince of Wales Graving Dock, Leith, has been tried swung. Some idea may be formed of the power of the hydraulic machine fitted up by Sir William Armstrong, when it is stated that the bridge is 214 ft. long, 39 ft. broad, and weighs 600 tons, and that the machine easily moved the ponderous bridge on its pivot. This trial was made merely for the satisfaction of the engineers and other persons interested; but before the Harbor and Dock Commissioners take the bridge off the contractors' hands a more formal testing of the machinery will take place. A double line of rails have been laid on the bridge, and the railway lines connected with the Caledonian and North British systems in North and South Leith will be brought to the bridge as soon as it is thoroughly complete. The centre of the bridge will be appropriated to railway and carriage traffic, and on each side will be convenient footpaths for pedestrians. It is expected that the contractors will complete the whole of the works in a few weeks.—*Iron.*

Proposal for a Third Alpine Tunnel.—Italy appears to derive more benefit from the prevailing passion among engineers for great works than any other country. To those fond of tunnel-making her Alps afford the most brilliant field of activity. She already has the Mont Cenis tunnel, that of Saint Gothard is under way, and now it is proposed to pierce grand old St. Bernard by a passage way 5,800 metres (about 6,380 yards long). It is proposed, says "Iron," to construct this tunnel in four sections, by means of side galleries, so that the work may be completed in three or four years. These working galleries will remain open afterwards for ventilation and other uses. A peculiar feature is that it is proposed to form a station within this tunnel by widening 600 metres of the level, central portion; one of the objects which has led to this singular plan is, that possibly for economy's sake two light trains which had made the ascent separately might be joined together for the descent on the other side. It is also argued that with such an arrangement many tourists would be glad in the summer season to attain the summits of the group of the Grand St. Bernard by the inclined passages already referred to, and at the mouths of which stations for refreshment, and even for lodging, might be established. The cost of this part of the work is estimated at only 17,000,000 francs; but to make the great tunnel of use, a railroad will have to be built through a most difficult country requiring several other tunnels of less size; so that the cost of the whole work is put (in advance) at 90,000,000 francs, or close on $18,000,000, gold.

Aqua da Verrugas.—A correspondent of the New York "Times" describes this structure (built by the Baltimore Bridge Co.), on the line of the Callao & Oroya R., Peru, as one of the finest engineering works in existence,—remarkable as the highest of the kind in the world, and for surpassing all others of the same class in its perfect system of bracing and connections. The viaduct crosses a wild and picturesque ravine, through which foams and flashes a small mountain torrent. It consists of four deck spans (Fink truss), three of which are 110 ft. long, and one, the central, 125 ft. The spans rest on piers built of wrought-iron columns, and these piers are 50 ft. long by 15 ft. wide on top. There being three piers, the total length of the viaduct is 575 ft. These piers are the great feature of interest, and are, respectively, 145, 252, and 187 ft. high. Each consists of 12 legs (in a rectange), composed of a series of wrought-iron six-segment columns, in lengths of 25 ft., connections being made by cast-iron joint-boxes, having tenons on each end running into the column. The tenons and the face of the casting against which the column bears are machine dressed, so as to face. The columns have an exterior diameter of 12 in., and a diameter, including flanges, of 16 in. The legs of the piers are securely fastened together by three systems of brace-rods running transversely, longitudinally and laterally, and braced by longitudinal and transverse iron shutes. These braces and shutes are connected at the joints by bolts and small pins. Transversely, the pin has the shape of an inverted W, two legs batter in and two out, the outer having a batter of 1 ft. in 12, and the inner so inclined as to make the above-mentioned shape. There are three of these W's in a pier, each containing four legs, making 12 in all. The piers were raised within themselves, tier upon tier, the material being drawn up by a common windlass. The side spans were raised with the usual scaffolding, but the central span, having been put together on a staging a few feet above the ground, was lifted bodily 250 ft. This method is said to be quicker and more economical than any other, as a single span of masonry would have cost twice as much, and not been so safe.

Hoosac Tunnel Ventilation.—The theory that the tunnel would be ventilated without the aid of the central shaft is, says the Springfield "Republican," practically established. Mr. Shanly recently passed through, and reports a fine breeze from east to west through the entire length, which, as, the week before, the current was strong from west to east, fully confirms the belief that nature will attend to the ventilation, without the aid of artificial chimneys. There will be a little dripping of water at short distances at several points. This would not injure trains any more than a light shower; but, to prevent injury to bed, there will be erected over the wet portions roofs of galvanized iron to carry the water off to the gutters on the sides of the track.

The dissection of continents by inter-oceanic canals, seems to be one of the principal tendencies of the day. The latest aspirant for the somewhat doubtful financial honors of such an undertaking is Mr. Theodore Tubini, banker of Athens, Greece, who has obtained a concession for a canal through the Isthmus of Corinth. The prism of the canal is to be 8½ metres (28⅝ ft.) deep and 12 metres (40 ft.) wide at bottom. At the centre will be a dock covering about 37,000 sq. yards. This work is to be finished in six years, and will cost four million dollars. Our own canal, through the Isthmus of Darien, is by no means laid on the shelf, and the advantages it offers to this country in particular, but also to all others, are a strong ground for expecting a steady effort to carry out the work. Three routes have been surveyed, one across the Isthmus of Darien proper, one by the Isthmus of Tehuantepec, and the third by Lake Nicaragua. The second of these lines may be left out of consideration, partly on account of the high elevation to be surmounted, and partly because the water supply is not certain for all the levels. By either of the other routes the cost would be $60,000,000 or thereabouts. At Darien the highest level is 120 ft.

above the sea, and a tunnel three miles long would be needed. Against these advantages are to be placed the existence of good natural harbors and the shortness of the canal. By the Nicaragua route tunnelling would be avoided, the height of lockage is only 103 ft., and the summit level is formed by an inland sea 35 miles wide. This would undoubtedly offer decided advantages as a quiet harbor for repairs, etc., and for transhipment of freight. Ships from California would also save nearly a thousand miles over the Darien route. These different routes, with the reports of the surveying parties who have examined them, are under consideration by General Humphreys, Chief of U. S. Engineers, and Prof. Pierce of the Coast Survey, and these gentlemen will make a recommendation to Congress on the subject.—*Engineering and Mining Journal.*

ORDNANCE AND NAVAL.

A Copper-Clad Ship for Carrying Combustible Freight. — The importation of corrosive sublimate, vitriol, and similar dangerous compounds has heretofore been carried on to a small extent, says the Jersey City "Journal," owing to the damages ensuing to the ships used in their transportation, as the leakage and draining from the different named substances, when mixed in the bilge water of the vessels, has, in most instances, eaten the bottoms out of the vessels.

A company in England running to the East Indies first thought of using copper in the construction of their vessels as a preventive against the bugs that infest that locality, the said bugs being considered death to all wooden vessels, and instances have been shown of the successful depredations of the insects even on iron-clad ships. To obviate these drawbacks to commerce, a ship was built completely encased in copper.

The frame-work is of iron, which, however, is not exposed in the least. The outside is covered with sheets of thick copper, riveted in the same manner as the iron vessels. The whole interior of the ship is also made of copper, the inside copper being galvanized, the beams, and, in fact, every exposed part being completely protected by copper; the masts are of wood, but sheathed in copper from top to stem. The name of this copper monster is the Adirondack; she is a screw steamer, and is capable of carrying 7,000 tons, Custom House measurement, and is about 515 feet in length, being some seventy feet longer than any of the Oceanic Company's ships.

The White Star line have purchased this steamship for the purpose of carrying such freight as mentioned. Her upper deck has been fitted up with a large tank for carrying oil of vitriol in bulk, lunar caustic, potash, sal soda, and, in fact, all similar kinds of freight will be imported in larger quantities now, should the trial trip succeed, which there is every prospect of its doing. The Adirondack is now being got ready for her trip, and will arrive in this port in the course of a fortnight. She is coated on her outside with a preparation of fat and copal varnish, to protect her from the effects of sea water, and it is said that the reflection of the ship upon the ocean on a bright sunny day is like the reflection of the sun at sunset on a large building containing many windows, only on a larger scale. It is claimed that she can be seen at sea on such a day a distance of about seventeen miles.—*Am. Manufacturer.*

BOOK NOTICES.

Kohlrausch's Physical Measurements: An Introduction to Physical Measurements, with Appendices on Absolute Electrical Measurement, etc. By Dr. F. Kohlrausch. Translated from the Second German Edition by T. H. Waller and H. R. Procter. London: J. and A. Churchill. 1873. For sale by D. Van Nostrand.

Their work is intended to serve as a text-book for students in experimental physics, and consists mainly of a collection of the formulæ used in correcting and applying the results of the simpler experiments in weighing and measuring, heat, light, electricity, and magnetism, accompanied in each case by such an account of the method of observation employed as may suffice to render them intelligible.

The limits which the author assigned to himself are very clearly laid down in the translators' preface, in which we are informed that "descriptions of apparatus are but rarely given, as students mostly have instruments provided for them," and also that "the mathematical knowledge required is but very elementary, as the proofs of the formulæ are only given when they present no complex arguments;" but it should perhaps have been added that, even in cases where the apparatus is simple, outlines of the mode of performing an experiment are generally alone supplied, the teacher being left to explain to his pupils the niceties of arrangement and manipulation.

It is as a collection of formulæ that "Physical Measurements" is likely to prove most useful, and from this point of view the "Introduction" seems to us one of the best parts of the book. It contains the rules for finding the mean and probable errors of a set of observations, and for determining empirical constants by the method of least squares, together with hints as to how to shorten the labor often wasted in the calculation of corrections; points on which a short practical treatise like that here provided will afford great assistance to those who are not mathematicians.

The sections devoted to weighing and measuring are full and good, especially those which relate to the use of the balance, but heat and light are not treated of in an equally satisfactory manner.

The experiments on these subjects which are described are not numerous enough to satisfy the requirements of large laboratories. Moreover, sufficient attention seems scarcely to have been paid to the fact that students should be encouraged to apply corrections to the results of experiments which they perform, not so much on account of the more accurate numerical values thereby obtained, as for the sake of the excellent practice the necessary observations often afford, and the insight gained into the theoretical principles on which they are founded.

Nearly one-half of the book is given up to Electricity and Magnetism, subjects in the study of which assistance can be more readily rendered by the method of treatment here adopted than in those we have been discussing, as numerous mathematical formulæ are required which are in many cases obtained by calculations beyond the grasp of the less advanced pupils; and the Translators have considerably improved what was already good by several Appendices, among which one of the most important is that on Thomson's electrometer. Some preliminary sections are devoted to the reduction of observations made with the mirror and scale to angular measure, to the determination of the position of equilibrium and time of oscillation of a magnetic needle, and similar topics, while the methods of reading the various magnetometers and galvanometers, and the measurement of resistance and electromotive force, are afterwards discussed.

On the whole, the principal fault we have to find with the book is a want of fulness, especially in the earlier portions. It aims at supplying a want already felt, and which will become still more pressing as the number of those who make some progress in the study of Natural Science increases, and we are not aware of the existence of any manual which gives the information contained in it in an equally compact and handy form; while the tables, thirty in number, which fill the concluding pages, will often save time and trouble to those engaged in laboratory work. Although, then, as we have already pointed out, we consider it capable of very considerable improvement, yet probably most teachers of Experimental Physics will obtain some useful hints from its perusal, even if they do not adopt it as a text-book for their pupils.—*Abstract from Nature.*

NOTES ON A METALLURGICAL JOURNEY IN EUROPE. BY JOHN A. CHURCH, M. E. With 22 illustrations. New York, 1873. 8vo., pp. 102. D. Van Nostrand.

So much exact and valuable information on technical art is rarely crowded into the same space as is to be found in the one hundred closely printed pages of Mr. Church's "Notes" of his metallurgical journey in Europe. The topics discussed are concisely handled in the analytic method, and with a fulness of detail which makes the work of permanent value. The copper process at Agordo; the mercury works at Valalta; the lead works at Mechernich; the gold and silver works at Lend,—occupy 53 pages, rich in information and details drawn from the most authentic sources. Since 1870 the processes at Freiberg have been so much changed that Mr. Church's chapter of 28 pages devoted to them will be read with great interest. The lead and silver works of the Hartz Mountains, Clausthal, Lautenthal, and the copper process at Altenau, complete this useful and unpretending memoir, which appeared first in a series of articles in the "Engineering and Mining Journal" of New York during the past year.—*American Journal of Science and Arts.*

THE CONSERVATION OF ENERGY, BEING AN ELEMENTARY TREATISE ON ENERGY AND ITS LAWS. BY BALFOUR STEWART, LL. D., F. R.S. London: Henry S. King & Co. 1873. For sale by D. Van Nostrand.

In this work, one of the international scientific series, the author has in a singularly lucid manner contrived to popularize some of the most intricate problems in the philosophy of the physical sciences. Viewing the universe, as a whole, in the light of a vast physical machine, he introduces the neophyte to a view of its mode of working, so far as that is known. In the first chapter, atoms, the ultimate constituents of matter, and energy, their mode of action, are defined. The following exposition of the nature of the molecule and atom taken from somewhat farther on in the book is a good example of the author's perspicuous style; and as it regards a matter now frequently referred to in current literature, and though not very difficult of apprehension, still one rather hazily apprehended by the popular mind, it may be worth while to quote it. "Let us suppose," he says, "the continual subdivision of a grain of sand" until we arrive at "the smallest entity retaining all the properties of sand"—this is the molecule; and if we continue the subdivision further, "the molecule of sand separates itself into its chemical constituents, consisting of silica on the one side and oxygen on the other. Thus we arrive at last at the smallest body which can call itself silicon, and the smallest which can call itself oxygen," and "these constituents of the silica molecules are called atoms, so that we say the sand molecule is divisible into atoms of silica and oxygen." In the succeeding chapters the change of mechanical energy into heat is considered, and some of the most remarkable and important discoveries of the century in connection with this subject are explained, and the forces and energies of nature—gravitation, electricity, and the rest, defined, their transmutation of energy illustrating what is known as the correlation of the physical forces, and lastly, the dissipation of energy, the closing chapter being on "the position of life." One very interesting point is the reference to the ideas in physics of several of the leaders of thought in ancient times—to Heraclitus of Ephesus, Democritus, the originator of the doctrine of atoms, and Aristotle, regarding whom the author observes that they possessed great genius and intellectual power, but were deficient in physical conceptions, and that, in consequence, their ideas were not prolific. In the chapter on the dissipation of energy, he felicitously describes coal as the store which nature has laid up as a species of capital for us, while wood is our precarious yearly income, so that "we are thus at present very much in the position of a young heir, who has only recently come into his estate, and who, not content with the income, is rapidly squandering his realized property."—*Iron.*

SIMPLE PRACTICAL METHODS OF CALCULATING STRAINS ON GIRDERS, ARCHES, AND TRUSSES. BY E. W. YOUNG. London: Macmillan & Co. For sale by D. Van Nostrand.

This work fulfils the promise implied in the title, and, inasmuch as students as well as engineers differ in their tastes regarding the methods of dealing with practical problems, this work will undoubtedly become a favorite of a greater or less number.

It will, however, prove unsatisfactory to the majority of American engineers, by reason of the omission of the leading forms of trusses employed in this country. The methods of calculation are simple enough, but not more so than we find in the later works on this side of the Atlantic, while these latter present the advantage of discussing forms of bridges that are preferred here, but are rarely seen in Europe.

The type and plates of the book are unexceptionable.

ANIMAL LOCOMOTION; OR WALKING, SWIMMING, AND FLYING, WITH A DISSERTATION ON AERONAUTICS. By J. BELL PETTIGREW, M.D. London: Henry S. King & Co. For sale by D. Van Nostrand.

In this volume of Messrs. King's excellent International Science series we have an original work by a well-qualified scientist, on what may be termed the animal machine in motion. There is certainly no part of the animal mechanism in which there are finer evidences of adaptation than those employed in locomotion through either element; and when the subject comes to be examined in minute detail, and under the light of careful observation and exact science, many curious relations are perceived, and many indications present themselves of high practical importance. Thus it is made evident that walking, swimming, and flying are only modifications of each other, and that weight, instead of being an impediment to flight, is absolutely necessary to it, two facts of much encouragement to experimenters in aeronautics; farther, that although the wheel of the locomotive and the screw of a steamer differ from the limb of a quadruped and the fin of a fish, still the curves which go to form the wheel and screw are found in the travelling surfaces of all animals, whatever their mode or means of progression. From which, and other similar revelations with which Dr. Pettigrew's book teems, inventors may learn to go to nature for many a hint and help in other things besides artificial locomotion, if they only go the right way; although much has already been thus gained, even through merely superficial and empirical knowledge, as in the well-known instance of the construction of Eddystone lighthouse. And recent and more cafeful experiments have elicited the interesting fact that the undulation or wave made by the wing of an insect hovering or flying corresponds, in a marked manner, with the track described by stationary and progressive waves in fluids, and with the waves of sound—the wing acting on those very curves into which the atmosphere is naturally thrown in the transmission of sound. It would be impossible to follow the author through all the elaborate and minute details to which he introduces his readers, commencing with a description of the instruments of progression, and following with a full account of the laws and methods of working of the multiform organs, by which the immensely varied living forms move on land, on and in the water, and through the air. In the closing passages of this division, he observes that their "indomitable courage and miraculous powers invest" birds "with a superior dignity, and secure for their order almost a *duality of existence*," a remark the latter part of which recalls Sir Boyle Roche's famous axiom, that a man couldn't be in two places at once unless he was a bird. On the subject of aeronautics, Dr. Pettigrew, while stating his case temperately enough, seems sanguine of the ultimate success of the now systematic attempts to give to man the power of artificial flight. Reasoning from analogy and nature, he holds that the "tramway of the air may and will be traversed by man's ingenuity at some period or other." Weight is no obstacle, but rather favorable than otherwise, for progression through the air; and the materials and forces employed in flight are literally the same as those employed in walking and swimming; whilst now that, by steam, man has outraced the quadruped on land and the fish in the sea—each having been, "so to speak, beaten in its own domain"—the necessary physical power has been acquired. In this chapter the chief inventions for aerial locomotion are described and compared, and a "wave wing" and "aerial screw" designed by the author on scientific principles is advocated. In conclusion, he maintains that, however difficult his task, the aeronaut, in attempting to produce a flying machine, is not attempting an impossible thing. The movements of the tail of the fish and of the wing of the inseet, bat, and bird, can, as he shows, be readily imitated and reproduced, while in the analogical instances of the locomotive and steamboat, success was attained, not by servile imitation of living things, but by the production of motors adapted to land and water in accordance with natural laws, and in the presence of living models. And if the difficulties are greater in this than in the other cases, the reward will be correspondingly great. "Of the many mechanical problems before the world at present, perhaps there is none greater than that of aerial navigation. Past failures are not to be regarded as the harbingers of future defeats, for it is only within the last few years that the subject of artificial flight has been taken up in a true scientific spirit. Within a comparatively brief period an enormous mass of valuable data has been collected. As societies for the advancement of aeronautics have been established in Britain, America, France, and other countries, there is reason to believe that our knowledge of this difficult department of science will go on increasing until the knotty problem is finally solved. If the day should ever come, it will not be too much to affirm that it will inaugurate a new era in the history of mankind; and that great as the destiny of our race has been hitherto, it will be quite outlustred by the grandeur and magnitude of coming events." We must add that the volume is admirably illustrated, chiefly from original drawings by the author, which makes still more intelligible his very popular and lucid expositions.—*Iron.*

A TREATISE ON STEAM BOILERS: THEIR STRENGTH, CONSTRUCTION, AND ECONOMICAL WORKING. By ROBERT WILSON. London: Lockwood & Co. 1873. For sale by D Van Nostrand.

Mr. Wilson gives us, in a well-digested and arranged series of chapters, all the salient points of theory and practice, past and present, derived from various sources. Thus, after a preliminary *resumé* of the chief types of boilers which have been used, whence we infer that Mr. Wilson believes in the tubulous variety of the typical boiler of the future, without, however, being greatly enamored of any of its existing representatives, his readers are taken through a brief exposition of the various kinds of surfaces, cylindrical, spherical, cambered and flat, under which boiler-shells are classified; and they are then introduced to the materials, cast iron, wrought iron, and steel, of which boilers have been or are now made, with their special properties and characteristics; and then to the subjects of riveting, welding, and the special modes or designs of construction adopted. The mountings and fittings of boilers and furnaces are then successfully treated of, feed apparatus, safety-valves, steam and water gauges, blow-out appliances, steam domes, furnace doors and frames, fire bars, bridges, ashpits, etc.; especial stress being justly laid upon the necessity, means, and difficulties of making the connections thoroughly sound and tight. Incrustation, wear and tear, the safety-factor, testing, and explosions, each successively claim and receive attention; and the concluding chapters are devoted to the combustion of coal and coke, firing and the prevention of smoke; heating-surface; boiler-power, and the properties of saturated steam; the whole being suitably illustrated by diagrams, formulæ, and useful tables of various kinds.—*Iron.*

MISCELLANEOUS.

At a recent meeting of the Paris Academy, M. Cazin called attention to certain cases of intermittence in the voltaic current not previously observed. One of his experiments is as follows:—A voltaic circuit is formed with 20 Bunsen elements and a coil inclosing an iron tube. It may be opened or closed at will by means of a platinum point and a drop of mercury, which communicate respectively with the two rheophores. When the platinum does not touch the mercury, and the two are put in communication with the armatures of a condenser (formed with plate of glass, etc.), one hears a continuous sound in the iron core. The same effect is produced when, the condenser being suppressed, a layer of alcohol is interposed between the mercury and the platinum point. The sound ceases when the alcohol is removed, the platinum and mercury being separated by a layer of air; also when the point is immersed in the mercury. These facts (M. Cazin thinks) show that the current passes through the glass in the first case, and through the alcohol in the second, and that its passage is intermittent. The iron core undergoes a rapid succession of alternate magnetizations and demagnetizations. Each of the demagnetizations causes a slight sound in the core; the rapid succession of these producing the continuous sound heard. He considers the cause of the intermittence to be the condensing action of glass and alcohol. When the two faces of the insulating body, which are in contact with the rheophores, have acquired a certain potential, a discharge takes place through the insulating layer; the magnetism of the core increases during the charge of the condenser, and diminishes during its discharge. The sound is produced during the diminution of the magnetism.

Professor Hayes gives, in the "American Chemist," the following opinion regarding the formation of deposits in boiler flues: They are of two kinds, both of which are capable of corroding the iron rapidly, especially when the boilers are heated and in operation. The most common one consists of soot (nearly pure carbon) saturated with pyroligneous acid, and containing a large proportion of iron if the deposit is an old one, or very little iron if it has been recently formed. The other has a basis of soot and fine coal ashes (silicate of alumina), filled with sulphur acids, and containing more or less iron, the quality depending on the age of the deposit. The pyroligneous deposits are always occasioned by want of judgment in kindling and managing the fires. The boilers being cold, the fires are generally started with wood, pyroligneous acid then distils over into the tubes, and, collecting with the soot already there from the first kindling fires, forms the nucleus for the deposits, which soon become permanent and more dangerous every time wood is used in the fireplace afterward. The sulphur acid deposits derive their acids from the coals used, but the basis material, holding these acids, is at first occasioned by cleaning or shaking the grates soon after adding fresh charges of coal. Fine ashes are thus driven into the flues at the opportune moment for them to become absorbents for the sulphur compounds distilling from the coals, and the corrosion of the iron follows rapidly after the formation of these deposits.

A Novel and Simple Electric Light.—Dr. Geissler, of Bonn, Germany, whose name is inseparably associated with some of the most beautiful experiments that can be performed by the agency of electricity, makes an electrical vacuum tube that may be lighted without either induction coil or frictional machine. It consists of a tube an inch or so in diameter, filled with air as dry as can be obtained, and hermetically sealed after the introduction of a smaller exhausted tube. If this outward tube be rubbed with a piece of flannel, or any of the furs generally used in exciting the electrophorus, the inner tube will be illumined with flashes of mellow light. The light is faint at first, but gradually becomes brighter and softer. It is momentary in duration; but if the tube be rapidly frictioned, an optical delusion will render it continuous. If the operator have at his disposal a piece of vulcanite, previously excited, he may, after educing signs of electrical excitement within the tube, entirely dispense with the use of his flannel or fur. This will be found to minister very much to his personal ease and comfort. He may continue the experiments, and with enhanced effect, by moving the sheet of vulcanite rapidly up and down at a slight distance from the tube. This beautiful phenomenon is an effect of induction.

Economical Consumption of Fuel.—An exhibition of appliances adapted to the above purpose is about to be held in Manchester, by the Society for the Promotion of Scientific Industry. The exhibition will comprise: (1) Appliances which may be adapted to existing furnaces, etc., whereby an actual saving is effected in the consumption of fuel; (2) appliances which may be adapted to existing furnaces, etc., whereby waste heat is utilized; (3) new steam generators and furnaces, boilers, and engines specially adapted for the saving of fuel, and appliances whereby waste products are utilized, and the radiation of heat prevented, etc., etc. A variety of similar apparatus for manufacturing, agricultural, and domestic purposes, will also be exhibited. The exhibition promises to be interesting and instructive.

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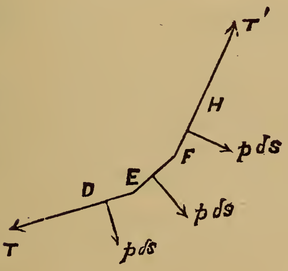
THEORY OF ARCHES.

(*Continued from page* 104.)

Again, take *three* elements, D E, E F, F H (Fig. 16), of the cord, each bearing the normal load $p\,d\,s = p\,d\,s = p\,d\,s$. In place of the little arcs, we use for clearness the chords of those arcs. Since the load around the whole curve C A B (Fig. 14) is supposed to be *uniform*, the arcs bearing the equal elements ($p\,d\,s$) of that load must also be equal, or D E = E F = F H. We have above proved T = T'. Hence the three sides D E, E F, and F H will arrange themselves symmetrically as in (Fig 16). Now, every other piece of the cord containing three elements will assume exactly the same slope as D H, since each such piece must equal D H in length and must be acted on by an equal and precisely similar system of forces. Consequently, the little chords D E, etc., must constitute a *regular polygon*, and the curve in which they are inscribed must be *constant* in curvature, in other words—a *circle*.

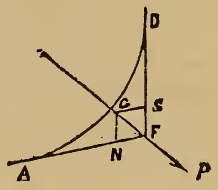
FIG. 16.



Therefore the curve of the cord C A B (Fig. 14) is the arc of a circle.

To form the triangle of forces for any point of a loaded circle as for A D (Fig. 17), draw the tangents at the extremities A and D. From the intersection, F, of these, lay off F N = F S, to represent the equal pulls at A and D. Then the diagonal F G = the resultant of the load, and the triangle F N G or F S G represents the forces acting on A D.

FIG. 17.



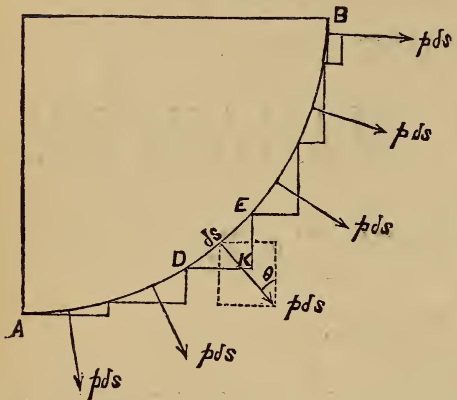
It is often easier to deal with a *uniform normal* load by resolving it into its vertical and horizontal components. The load on an element D E = ds of the quadrant A B (Fig. 18) is $= p\,d\,s$. The horizontal component of this load $= p\,d\,s \sin.\ \theta$, where θ = the angle made by the direction of pds with the vertical (or what is the same, the angle made by the tangent of ds with the horizontal). The vertical component $= pds \cos.\ \theta$. Consider the horizontal component ($pds \sin.\ \theta$) with reference to the vertical space over which it is distributed. This space is E K (Fig. 18) $= d\,s \sin.\ \theta$. Hence the *intensity* of the horizontal component

$$= \frac{p\,d\,s \sin\theta}{d\,s \sin\theta} = p.$$

So the vertical component ($p\ d\ s\ \cos\ \theta$) is distributed over a horizontal space = D K = $d\ s\ \cos\ \theta$, and therefore its *intensity* is

$$=\frac{p\ d\ s\ \cos\ \theta}{d\ s\ \cos\ \theta}=p.$$

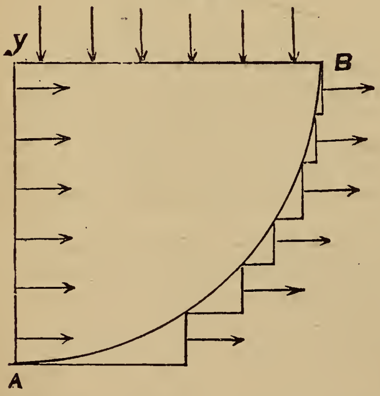
Fig. 18.



But p = the *intensity* of the normal force. Hence the original normal force at each point is equivalent to a horizontal and a vertical force, at that point, of equal intensity.

If we then construct little triangles on the curve A B (Fig. 19) such that their *vertical* sides shall be constant in length, the horizontal forces on these sides will be represented by lines of constant length. Transfer these forces in their lines of direction to A Y. A Y is the sum of all the vertical sides of the little triangles, and as the horizontal *intensity* is constant and equal to p, we have (if r = radius of the circle) p (A Y) = pr = total horizontal force on quadrant A B.

Fig. 19.



Similarly, if we draw a set of triangles on A B with all their *horizontal* sides of the same length, we may see that the total vertical force on A B is

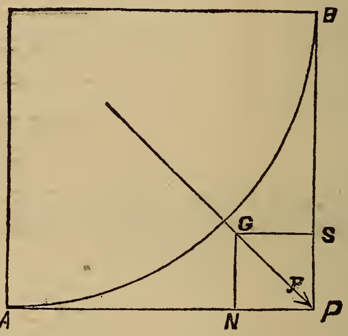
$$=p\ .\ (\mathrm{Y\ B})=p\ r.$$

Hence,

1. The resultant of the entire normal force on the quadrant A B is equal to the resultant of a horizontal and a vertical force each of which is = pr.

2. Therefore in the parallelogram of forces for the quadrant (Fig. 20), F S, which represents the pull along the cord at B, is the vertical component of P, while N F = pull at A, is the horizontal component of P. Each of these forces = pr. Therefore the constant pull all along the cord is = pr.

Fig. 20.



If we make the pull at the vertical point (B) = V, we have

$$\mathrm{H}=\mathrm{V}=\mathrm{T}=p\ r \quad . \quad . \quad (20.)$$

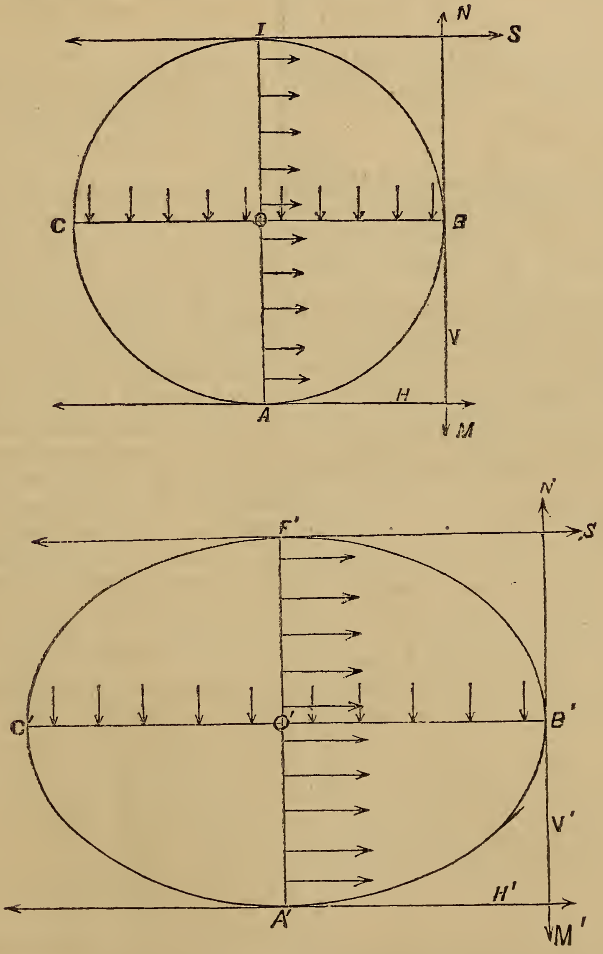
In practice a uniform normal force exists in the case of a cylinder filled with steam, or in a vertical cylinder filled with liquid Thrust instead of tension along A B exists when the normal force pushes inwards, as in the tubes of a steam boiler or an empty vertical cylinder immersed in water. In reference to arches, this discussion has its principal value as introductory to those that follow.

Case V.—In this case we obtain the curve and forces by parallel projections from the circle.

If we suppose a cylinder erected upon the circle (Fig. 21) as a base and cut it by an inclined plane whose line of intersection with the plane of the base shall be parallel to A I, we will get an ellipse whose vertical axis A′ I′ (Fig. 21) will = A I, and whose horizontal axis C′ B′ will be greater than

C B. All lines parallel to A I will be unchanged in length, while all parallel to C B will be increased in the proportion of C′ B′ to C B. Now, by the principle of parallel projections, the ellipse, which is the parallel projection of the circle, will be balanced under the forces which are the parallel projections of those under which the circle is balanced.

Fig. 21.



As we have seen, the circle is the curve assumed by the ring under a uniform horizontal and vertical force at each point of the same kind, and equal in intensity; for such a system of forces is equivalent to a constant normal force around the curve. For convenience, these forces are represented in Fig. (21) along the two diameters, each little line representing the force on a unit of distance. The pull around the ring is of course tangential to it, and is everywhere the same ($=pr$). This pull is represented at A and B by the arrows there.

In the ellipse, the *vertical* lines being unchanged, the total vertical force on the elliptic ring (= the sum of all the little vertical lines) is the same as it was in the circle, and if we call the vertical force on a quadrant V (= B M) for the circle and V′ (= B′ M′) for the ellipse, we will have

$$V = V' \quad . \quad . \quad . \quad (21.)$$

Notice, however, that in the ellipse the force V′ is distributed over the distance O′ B′ and not over a distance = O B. Hence the *intensity* of the force V′, or the amount of that force on each unit of distance, is not the same as in the circle. In the ellipse (Fig. 21) each little vertical line represents, therefore, the force on a distance greater than a unit. Let $O'B' = c\,OB$. Then to obtain the *intensity* of V′, divide it by the space over which it is distributed. Thus, let

$$p_v = \frac{V}{OB} \text{ and } p_x = \frac{H}{AO}$$

represent the vertical and horizontal intensities in the circle. We have already seen that in the circle

$$p_v = p_x = p.$$

Let p'_v and p'_x represent the vertical and horizontal intensities in the ellipse. Then

$$p'_v = \frac{V'}{O'B} = \frac{V}{c\,.OB} = \frac{p_v}{c} \qquad (22.)$$

The lines representing the "pulls" at B and C (as B N) are also unchanged. Hence the pulls at those points in the elliptic ring are the same as in the circular; that is they are equal to $V' = V$.

The *horizontal* lines are all increased in length in the ratio $1 : c$. Hence the sum of the lines representing the horizontal force on a quadrant of the ellipse (as I′ S′) is greater than the corresponding line (I S) in the circle in the above ratio. Therefore if H′= the horizontal force on the elliptical quadrant,

$$H' = c\,.\,H \qquad . \quad . \qquad (23.)$$

The length over which this force H′ is distributed (A′ O′) does not change, however, and hence the little horizontal lines in both figures represent the force on a unit of distance. Hence the *intensity* of the horizontal force in the ellipse has increased just as the length of the lines, or from the equation.

$$p'_x = \frac{H'}{A'O'} = \frac{c.H}{AO} = c\,p_x \qquad (24.)$$

The horizontal pull in the ring at A′ or I′ being equal to the horizontal force on a quadrant is

$$H' = c.H = c.V = c.V' \qquad . \quad . \qquad (25.)$$

Hence the "pull" around the ellipse is *not* constant as it was in the circle. The pulls at B′ and A′ are as

$$V' : H' : : 1 : c$$

But

$$A'I' : C'B' : : 1 : c.$$

Therefore,

1. The pulls in an elliptical ring are as the axes to which they are parallel.

Again the intensities in the ellipse are

$$p'_v : p'_x : : \frac{p_v}{c} : c\,p_x : : \frac{1}{c} : c : : 1 : c^2$$

And

$$(A'I')^2 : (C'B')^2 : : 1 : c^2$$

Therefore,

2. The *intensities* of the forces in an ellipse are as the *squares* of the axes to which they are parallel.

From this proportion we have

$$c = \sqrt{\frac{p'_x}{p'_v}} \qquad . \quad . \quad . \qquad (26\ )$$

It will be noted in the elliptic ring that the resultant of the little horizontal and vertical loads at any point is not *normal* to the curve except at the extremities of the axes.

Let us determine the pulls and the relations between the forces at other points besides the extremities of the vertical and horizontal axes of the ellipse.

In the circle (Fig. 22) if we resolve the forces along any two rectangular axes as $A_1 I_1$ and $C_1 B_1$, we shall have evidently the same relations between them as when resolved along a vertical and horizontal axis. Now the three parallel lines, viz., the diameter, $A_1 I_1$, and the tangents at C_1 and B_1, are projected in the ellipse into three *parallel* lines, viz.: A'_1, I'_1, and the tangents at C'_1 and B'_1. Similarly C_1, B_1, and the tangents at A_1 and I_1 continue parallel in the ellipse. Hence *rectangular* diameters of the circle become *conjugate* in the ellipse. The lines representing the forces perpendicular to $C_1 B_1$ in the circle become parallel to $O'I'_1$ in the ellipse, and are changed in length just as $O'I'_1$ is changed from $O I_1$. So the forces which are parallel to $C_1 O$ in the circle become parallel to $C'_1 O'$ in the ellipse, and vary as $C'_1 O'$ does from $C_1 O$.

Let $O'I'_1 = r'$ and $O C'_1 = r''$ and let the total force parallel to $O'I'_1$ on a quadrant (such as $C'_1 I'_1$ or $I'_1 B'_1$) of the ellipse be $= V_1$ and that parallel to $O'B_1'$ be$=H_1$. Then if $r =$ radius of the circle, we have (since the force on a quadrant of the circle as $C_1 I_1$ is $= H = V = T$)

$$\left.\begin{array}{ll} H : H_1 : : r : r'' & \therefore H_1 = \dfrac{H.r''}{r} \\ V : V_1 : : r : r' & \therefore V_1 = \dfrac{V\,r'}{r} = \dfrac{H.r'}{r} \\ & \therefore H_1 : V_1 : : r'' : r' \end{array}\right\} \quad (27.)$$

H_1 is equal to the pull along the ring at A'_1 or I'_1, and V_1 is that at C'_1 and B'_1.

Hence *proposition* 1 may be applied generally to all conjugate diameters in the ellipse; that is,

3. The total pulls along the ring at the extremities of any two conjugate diameters, are as the diameters to which they are parallel.

Again, the *intensities* being equal to the total loads divided by the surfaces over which they are distributed, let

p'_{y_1} = intensity of load parallel to O′ I′$_1$,
p'_{x_1} " " " C′$_1$ O′

Then

$$\left.\begin{aligned} p'_{y_1} &= \frac{V_1}{O'C'_1} = \frac{V\,r'}{r.r''} = p_y\,\frac{r'}{r''} \\ p'_{x_1} &= \frac{H_1}{O'\,I_1{}'} = \frac{H\,r''}{r\,.\,r''} = p_x\,\frac{r''}{r'} \\ \therefore p'_{y_1} : p'_{x_1} &: : p_y\,\frac{r'}{r''} : p_x\,\frac{r''}{r'} : : \frac{r'}{r''} : \\ &\frac{r''}{r'} : : r'^2 : r''^2 \end{aligned}\right\}(28.)$$

Hence for *proposition* 2, we may read,

4. The *intensities* of a pair of conjugate loads are to each other as the *squares* of the conjugate diameters to which they are respectively parallel.

To pass from one set of conjugate forces on the ellipse to another; let

p'_{x_1} and p'_{y_1} be the intensities parallel to one set of conjugate diameters.
H_1 and V_1 be total pulls parallel to same set of conjugate diameters.
r'' r' be the conjugate semidiameters.

Also let

$$p'_{1x_1},\ p'_{1y_1},\ H'_1,\ V'_1,\ r''_1,\ r'_1$$

be the corresponding quantities for the other set. Then

$$\left.\begin{aligned} p'_{x_1} &= p_x\,\frac{r''}{r'} & \therefore\ p_x &= p'_{x_1}\,\frac{r'}{r''} \\ p'_{1x_1} &= p_x\,\frac{r''_1}{r'_1} & \therefore\ p'_{1x_1} &= p'_{x_1}\,\frac{r'\,r''_1}{r'_1\,r''} \\ &\text{Also,} \\ H_1 &= \frac{H.r''}{r} & \text{or } H &= \frac{H_1\,r}{r''} \\ H_1{}' &= \frac{H\,r''_1}{r} & \therefore\ H'_1 &= \frac{H_1\,r''_1}{r''} \\ &\text{Similarly} \\ p_1{}'_{y_1} &= p'_{y_1}\,\frac{r''\,r'_1}{r'\,r''_1} \\ V_1{}' &= V_1\,\frac{r'_1}{r'} \end{aligned}\right\}(29.)$$

The ellipse (Figs. 21 and 22) is the form assumed by a cord under a load composed of horizontal and vertical components which are constant along the horizontal and vertical lines, but which differ from each other in intensity.

The diameter C′ B′ of the ellipse (Fig. 21) might have been made *shorter* instead of *longer* than that of the circle, if required.

Cor.—If one set of the forces are vertical and the other not horizontal, but inclined at an angle to the horizon (Fig. 23), we still have an ellipse, the directions of the forces giving the directions of two conjugate diameters (A′$_1$ O′ and B′$_1$ O′). Then, if p'_{x_1} = the intensity of the inclined force and p'_{y_1} = intensity of the vertical force, we have by proposition 4,

$$p'_{x_1} : p'_{y_1} : : (B_1{}'\,O')^2 : (A_1{}'\,O')^2$$

So from proposition 3, if V_1 = pull along the cord at B$_1$′ or C$_1$′ and H_1 = that at A$_1$′

$$H_1 : V_1 : : B_1{}'\,O' : A_1{}'\,O'.$$

From the first of these propositions we have the ratio of the conjugate diameters; and from the second we find the pulls at the extremities of those diameters.

Knowing two conjugate diameters and the angle (90°–*j*) between them we can readily obtain the ellipse.

To obtain the pulls at the extremities of any diameter, such as C$_1$ B$_1$.

This is merely passing from one set of conjugate diameters to another and equation (29) gives the pull at B$_1$, for instance, as

$$V_1{}' = V_1\,\frac{O'\,K}{O'\,A_1{}'}$$

(O′ K being conjugate to C$_1$ O′ B$_1$), etc., etc.

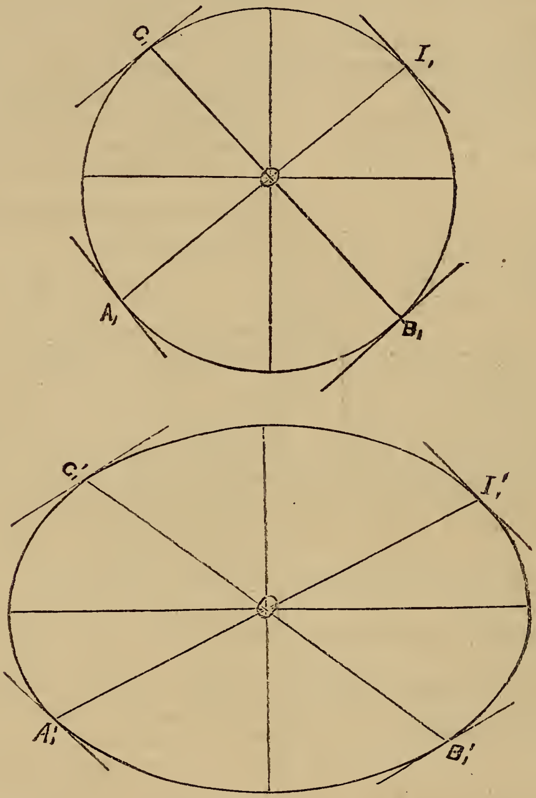
An important fact is now to be noted. Whenever the load on a cord is entirely *normal* to it, at that point the pull along the cord is equal to the intensity of the normal load multiplied by the radius of curvature.

For the cord *at that point* is similarly situated to a circular cord of the same curvature and under a load of the same intensity.

Thus, in the ellipse (Fig. 21) the action of the load at the extremities of the axes is entirely *normal*, for at A′ and I′ the horizontal component of the load vanishes and leaves only the vertical, which, *at these points*, is *normal* to the curve. So at C′ and B′ only the horizontal load has value, and its action is there normal to the curve.

Consider the elementary arc, *ds*, at A′, for instance, which is subjected to this normal load. It is balanced under the equal pulls $T = T'$ (Fig. 24) coming from the adjoining parts of the cord, and the normal load *pds*, which gives it its curvature. Imagine a circle under a constant normal force of intensity $=p$. Take an equal little arc $d\,s$ of it, loaded with a normal load $=$ *pds*. Then, if it be acted on at its two ends by tensions $= T = T'$, it is evident that it will have the same curvature as the arc of the ellipse; or, conversely, if it has *the same curvature*, the pull around the circle *must* be $= T = T'$.

FIG. 22.



Hence, having given the load on the curve at any point where it is *normal*, we determine easily the pull along the cord at that point. For, in the circle,

$$H = V = T = p_x\, r = p_y\, r = p\, r$$

and in the ellipse at A′

$$H' = p'_y\, \rho$$

Where $\rho =$ radius of curvature. If A′ O, $= r$ and O′ B′ $= c\,r$ in the ellipse (Fig. 21) we have at A′

$$\rho = \frac{c^2\, r^2}{r} = c^2\, r.$$

$$\therefore\ H' = p'_y\,.\,c^2\, r = \frac{p_y}{c} c^2\, r = c\,p\,r = c\,H. \quad (30.)$$

So in the parabola under uniform vertical loads (Case I.) we have seen that $H = 2\,p\,m$ (Rankine's C. E. p. 165). But $H = p\,\rho = 2\,p\,m$ (since $\rho = 2\,m$ at the vertex).

If the load be *everywhere* normal to the cord, the above equation will apply to every point, or

$$T = p\,\rho$$

be a general equation of the curve.

And further, when the load is everywhere normal we have already seen that the pull along the cord must be *constant*, as there is no tangential force to change it. Hence.

$$T = p\,\rho = \text{a constant.} \quad (31.)$$

When the load p is constant, of course, ρ must be constant too, and we have the circle already discussed. When p varies, ρ must *vary inversely* as p.

Case VI.—If p increases in value just in proportion to the distance of the points of the cord above a horizontal line M N (Fig. 25), the cord assumes the shape of the hydrostatic arch. This curve possesses geometrically the loops shown in the figure and may be extended indefinitely, but for our purpose it is evidently only necessary to discuss that part between the points C and B (Fig. 26) where the tangents are vertical.

FIG. 23.

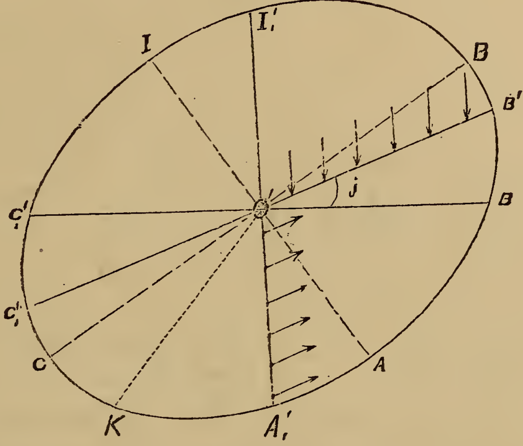
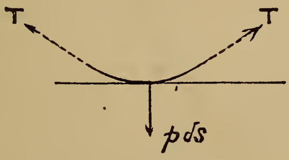


FIG. 24.



Taking L (Fig. 26) for the origin, if the intensity of the load then be y_0 (= A L) multiplied by a constant, or wy_0, then at any other point it is = wy.

Hence the equation of the curve is

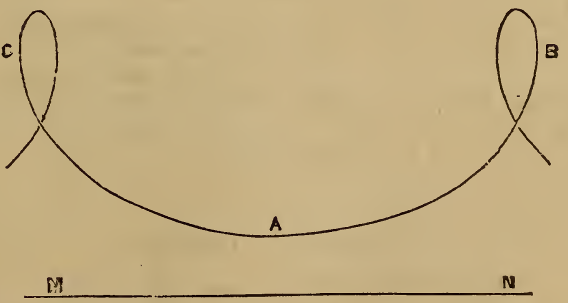
$$T = p\,\rho = w\,y\,\rho = w\,y_0\,\rho_0 = \text{a constant}$$

(y_0 and ρ_0 are the values of the ordinate and radius of curvature at A).

Let us resolve the normal load on C A B as we did in the circle, into its horizontal and vertical components. As was the case in the circle, these will be *for each point* equal in *intensity* to each other and also to the *normal* force, or

$$p = p_x = p_y.$$

FIG. 25.



But these quantities are no longer constant (as in the circle) all along the curve, but vary from point to point.

If we form the parallelogram of forces for any arc A D (as in Fig. 27) the side N F = F S, since H = T = a constant, and F G must represent the resultant of the whole load on A D both in amount and direction.

The vertical component, F E of F G, is equal to the vertical component S X of S F, or

Vertical load on A D = T sin i = H sin i.

At B the vertical load $= T = H = V$ (since $i = 90°$ there).

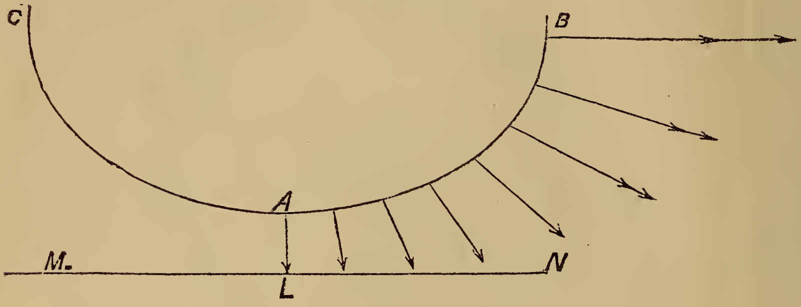
So the horizontal component of the total load on A D is G E, and since

$$NF = GS = GE + FX$$

we have horizontal load on

$$AD = GE = NF - FX = H - H\cos i = H(1 - \cos i),$$

FIG. 26.



At B, $i = 90°$ ∴

Horizontal load on A B $= H$

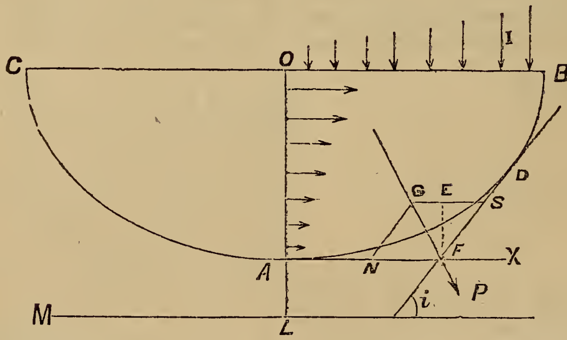
On the arc D B

Horizontal load $= H - H(1 - \cos i) = H \cos i$.

The *vertical* load on A D may be thus expressed

$$H \sin i = \int_0^x p_y\, dx = w \int_0^x y\, dx = w\, y_0\, \rho_0 \sin i \quad (32.)$$

FIG. 27.



The *horizontal* load thus

$$H(1 - \cos i) = w\, y_0\, \rho_0 (1 - \cos i) = \int_{y_0}^{y} p_x\, dy =$$

$$w \int_{y_0}^{y} y dy = w.\frac{y^2 - y_0^2}{2} \quad (33.)$$

And if y_1 = ordinate of B, the horizontal load on A B is

$$H = w \frac{y_1^2 - y_0^3}{2} \quad (34.)$$

For formula for radius of curvature see Rankine, C. E., p.

The equation $T = H = w\, y_0\, \rho_0 = w\, y\, \rho$, enables us to solve problems similar to those under the parabola.

(To be continued.)

NOTES ON IRON.*

BY THOMAS MORRIS, Manager of Dallam Forge, Warrington.

From "Iron."

What is this material called iron—this most useful of all metals—the intrinsic value of which exceeds all others, and which, in proportion to its use, should be the cause of progress of civilization in the world wherever it is manufactured—a substance whose extent of consumption any by nation,

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[*] Read at the Warrington Literary and Philosophical Society.

both in times gone by and at the present day, indicates very truly the degree of its advance in the arts and sciences? If we ask the geologist, he tells us that it impregnated the waters of the old red sandstone period, and tinged with rusty red the whole of that system; that it now appears in the segregated form of thin layers and bands of ironstone; that its ores are found more or less in all parts of the world, either as beds in the sedimentary rocks, or in the massive deposits in the olden rocks; that the United Kingdom derives its principal supply from the earthy carbonates of the coal measures, from the carboniferous formations where some particular coal-fields possess large deposits of rich hæmatite ore —instance the Cumberland and Lancashire district; from the oolitic beds of Cleveland and of South Yorkshire, where it is found from a few inches to 20 and 30 ft. thick; and those extraordinary carbonaceous blackband ores of Scotland where the richest deposits hitherto discovered are found. The meteorologist tells us the sun and the atmosphere played a most important part during the carboniferous era, and that now we are consuming the bottled-up sunlight of millions of years past in the making of iron. Again, iron in the shape of falling meteors has been found, and from one of these bodies a Persian Emperor had made two sabres, one knife, and one dagger. This "iron of lightning," or thunderbolt, could not be worked up by itself, but must have been mixed with one-fourth of common iron before the Tubal Cain of that day did his master's bidding. It would be a wrinkle worth knowing how he obtained the mixture. The mineralogist has been consulted, and he simply says that he has given us the various degrees of hardness of minerals, determined the idea of the species, and fixed the principle of classification. Coming to our nearer friend the metallurgist, he lets us know the numerous combinations and analyses of the particular metal we wish to study; what mechanical and chemical sciences are involved to complete the separation of the metal in that condition of purity desired by the manufacturer; what flux will best suit to form a glass with the multifarious ores during their fusion in that huge laboratory, the smelting-furnace. He tells us that without flux to separate the earthy matter from the ores, glasses would be formed, instead of the carburet of iron, and slags, and that the best known flux for nine-tenths of the ores is limestone, which is incapable of holding iron in solution at high temperatures; that there must be blown under pressure from 6 to 10 tons of atmospheric air in the furnace to produce the required oxygen for the reduction of 1 ton of pig-iron from the ore. Besides this, he can, if he will, tell us his utter inability to produce the same quality, or the same quantity of iron during the smelting process from two different ores. Yes, all his skill in the science of chemistry, his numerous experiments and analyses, have signally failed to furnish him with this grand object. Undoubtedly his assiduity in the science of chemistry has taught him judiciously to mix the ores given him by nature, and thereby to produce a suitable article for his customer; but inasmuch as the ores differ in their component parts, as the coal or fuel differs in its constituents, whether he uses hot or cold blast, so does he give us a cast metal commercially called pig-iron, at the price it will fetch in the market. And it is from this market that the finished iron manufacturers (as in Warrington) take it in hand, and by two distinct processes convert it into bars, plates, wire, etc.

We have arrived now at the puddling process, which is replete with interest, consisting as it does of converting cast metal into malleable iron. The present system of puddling as carried on almost universally with few modifications (which shall be named), was invented by an iron-master of the name of Cort, about the year 1780, the bed of whose furnace was made of sand. When the carburet of iron was refined, many of its impurities (especially the carbon, which is the metalloid causing fluidity) were driven from it; hence when the pig-iron was melted, it assumed the form of grain. If the carbon had been left in the pig-metal, the bed of the furnace could not have stood; besides, silica is fatal to iron, causing what is technically known as shortness or extreme brittleness. The deteriorating influence which sand or silica had on the iron when worked in contact with it was seen some years afterwards by Mr. Samuel Baldwin Rogers, who introduced the present system of iron bottoms to furnaces, which eventually did away with the finery process. Both of these gentlemen died in poverty, yet their inventions in their day were as much a desideratum, and were the cause of greater revolutions in the iron trade of that time than the Bessemer process or Danks' rotary puddler in our time. Mr. Joseph Hall, of Tipton, introduced the present pig-boiling process, doing away with the refining process. Many imagine that the gentleman with the cloven foot invented puddling, and I confess that for four or five months in the year it is one of the most distressing processes to the physical system of all manual labor, yet puddlers don't all stagger from the furnace fainting at the age of forty, as a certain special newspaper commissioner would have us believe. These joint inventions were the means of this kingdom taking the lead of all other nations in the iron trade, for up to this time we were dependent for our supplies upon Norway, Russia, and Sweden; from the latter place, even now, a large amount of their produce finds its way into England.

In describing this puddling process, it should be explained that the furnace is divided into two compartments, separated by a bridge about 12 in. thick and 14 in. high. Over this the flame passes from the grate and comes in contact with the iron, and after it has done duty there passes around the boilers, generating the steam necessary for driving the machinery required for forging and rolling the iron. The chamber or compartment into which the pig-metal is charged consists of iron plates, forming the bottom and sides, which are lined with refractory slags, rich in oxides of iron. In changing the heat, slags and scales from the hammers and rollers are thrown on the hearth or bottom, and on this the charge of pig-metal, consisting of 510 lbs. to 540 lbs. Fuel is then thrown in the grate, and in about 25 or 40 min. this carburet of iron becomes liquid, and assumes the form of a molten plate of iron some 1½ to 2 in. thick. Being heavier than the slags, the latter pass through it and rise to the top. In passing, the oxygen of the silicates combines with the carbon of the iron and decarbonizes it, but unless the iron is agitated it would not become malleable. Hence the puddler, with a bar called a rabble, agitates the metal, thus bringing the oxygen of the silicate in contact with the carbon and other impurities of the iron. As the carbon is leaving the metal its atoms expand and become of less specific gravity, and it throws off carbonic oxide gas, the blue flame of which is plainly seen by any one who watches the process. The puddler at this stage must be incessant in his operation, for the transformation scene is coming, and the crude iron is becoming malleable. The boiling of the mass is kept up by the fresh energy of the puddler, until, as the carbon diminishes, the atoms of the iron begin to knit or agglutinate together in a soft spongy consistency, the cinder taking the place of the once molten iron. The iron is now as sensitive to oxygen as the human lungs would be if inhaling pure oxygen ; it lives, as it were, too fast. It is at this point the smoke-preventers are puzzled, but a deoxidizing flame is kept on the iron while it is being kneaded and divided into balls preparatory to being brought out of the furnace; which when done, the lump is taken to the hammer and beaten into the required shape for rolling it into the puddled bar of commerce. This operation is called shingling.

From what has been said you will readily understand that the puddling operation consists of chemical combinations and mechanical application; and the inventions brought forward to assist the puddler in his part of the business are legion. The schemes tried to prevent smoke, save fuel, etc., etc., may be counted by scores. Quacks by the dozen have sprung up with physic to throw in the molten iron during the process, to drive off the deleterious substances, the one idea being that the iron would have a greater affinity for their dose than it had for the metalloids, carbon, phosphorus, and silicon, and so leave the iron pure. None of these recipés, however, have been so effectual as to warrant their continued and general use. Mr. Bessemer, some twenty-five or thirty years ago, accomplished the grand idea of forcing air through a molten mass, anticipating that the oxygen of the air would decarbonize the carburet and give him malleable iron ; but he failed, for when the iron had given up its last equivalent of carbon to the oxygen it commenced to burn it up. Besides, it lacked the kneading, or mechanical part of the operation. The chemical part he got over so far as to produce a metal thoroughly tenacious ; and its resistance to wear proves it to be the most durable and economical material for railway and other purposes. This invention of Bessemer's awakened metallurgists, and gave rise to several inventions for steel-making, but up to the present time there is only one invention of any practical importance, and that is the Siemens-Martin process.

About the same time as Bessemer was completing his inventions two gentlemen, Mr. Tooth, of London, and Mr. Walker, of Wolverhampton, brought out patents for oscillating and rotating puddling furnaces, which proved a step in the right direction. Somehow they got across, and their scheme was going when Mr. Menelaus, of Dowlais, bought up their rights, built a forge, and made some good iron. But he found several obstacles in his way, the principal one being the lining of the furnace, which he could not get to stand the severe wear and tear of the metal, and on this rock he came to grief. But this rotary principle had made its impression upon the minds of many people in this country and in America, and more especially upon Mr. Danks. This gentleman was born in West Bromwich, South Staffordshire. He was a puddler by trade, but left that part of the country at the age of twenty for Scotland. After working there three or four years he went to America, and was eventually engaged in the Cincinnati Railway Ironworks Company as their Superintendent. In 1868 this representative of English thought and skill, assisted by American cash and enterprise, built the first experimental rotary furnace, differing from that of Mr. Menelaus only in the flue of the furnace being movable. So significant was this improvement that it led to success, and the patent is now being worked in many parts of England and on the Continent. Complete puddler as is this furnace, it has the fault of producing only one ball, whatever the charge may be. And to produce balls of 100 lbs. or 200 lbs. weight only by this machine would increase the cost of its production. The rolling machinery employed at the present day is only calculated to forge and roll this weight of ball; hence the iron manufacturer, whose production consists of small bars, sheets, and hoops, cannot apply it.

Before leaving the puddling operation I should mention another very interesting principle of making iron which is undergoing a crucial test as to its commercial practicability, and that is a plan worked by Messrs. Gerhard and Caddick, of Bradley, South Stafford, who say that the bloom is made direct from the ore (mark, no smelting, and 50 to 60 per cent. of coal saved), which, having been ground, is mixed with lime and pitch, and then baked in a coke oven. This becomes the pig iron. A furnace is charged with it, and in half-an hour the charge is ready for the hammer. Elba and Barrow iron is at present being used, and excellent finished iron is being turned out.

We have now got to the puddled ball, in which, although it has been kneaded, the particles are in a very loose state, and require the repeated blows of the heavy forge or steam hammer, to knock out the slag which still attaches itself. Truran says the puddled ball is like grains separated by a thin film of extraneous matter (cinder), and when shingled the grains are brought closer together. When rolled into a bar 12 ft. long, each particle is about 9 in. long. Cut this bar into lengths, pile and roll, and we find in one inch of its section as many threads or fibres as were seen in 80 in. of the ball. Truran would have us assume that all iron is fibrous in the puddled bar, and consequently that it must be fibrous in the finished bar. This is a mistake, for often enough the puddled bar is crystallized, and no matter how many times this class of iron is worked over again, fibres cannot be developed. I have mentioned the fibrous bar, which is tough and ductile, hot or cold; and the cold short or crystallized bar. But there is the "hot short" quality; and this class of iron is as much to be guarded against as the cold short. For while the engineer who is constructing a bridge or building a vessel dreads the cold short iron, so does the blacksmith and the boiler maker dread the hot short. The iron manufacturer is the greatest sufferer from this class of iron, for after the iron has passed all its processes, its characteristics are seen in the finished iron in the shape of small cracks, at times so minute that an experienced eye only can detect them, and when found, the bar must be thrown to the scrap heap. Indirectly, too, the iron-master comes in for blame and cost, for if this defect is not detected before leaving the works, and the consumer does not find it working hot to the shape he requires, he immediately demands compensation from the manufacturer, or returns the iron upon his hands. In Wales, at one time (it is somewhat improved now), iron was so short when red, that the rough or puddled bar would drop in pieces while rolling at the forge rolls. The method of working up these short bits into finished iron, principally rails, was to make a large pile, and having a full-sized bottom to start from, it was built up to the required weight. In this manner the commonest of iron made from the lowest of ores, containing a large amount of iron pyrites, was worked up and made suitable for rails. Makers of high-class iron are very careful to avoid this. Red short iron is that which cracks when bent or punched at a red heat, although it may be sufficiently tenacious when cold. Cold short iron, on the contrary, is weak and brittle when cold, but can be worked without difficulty when hot.

The puddled bar is now before us, and must go through process No. 2 before it is fit for commercial uses. Hence it is cut down into suitable lengths, taken to the finishing mill, when it is piled up to the weight wanted, and charged in furnaces on bottoms made with sand. When at a welding heat, it is brought out and taken to the rollers again, and reduced to every imaginable shape or section desired by the customer.

We have now arrived at the finished or merchant bar; and leaving the iron-maker we will for a few minutes consult the engineer and theorist and learn what they have to say. The theorist imagines that by repeated workings all iron must be improved in its quality. This theory is wrong. Engineers and others state that all iron is subject to singular and important changes in its structure, and becomes crystallized. The causes they give for this molecular change are vibration, percussion, heat, magnetism, frost, or extreme cold. Many of these gentlemen found their belief on the remarks of others, without making a single experiment or observation of their own. And, therefore, for our better understanding them I shall give you some extracts taken from the "Transactions of the Institution of Civil Engineers" dated 1843.

Extract 1. Samples of broken axles were exhibited; some of them, being cut from different parts of the same axles, showed that at the journals, where the vibration was the most intense, the crystallization was increased to a great extent beyond what occurred in other parts of the same axles.

Extract 2. Mr. Moreland had frequently noticed that pins for chains, and pump rods, although of the best iron, would, if subjected to concussion, after a certain time, break suddenly, and that the fracture would exhibit a large crystallized texture. This was also frequently observed in the broken axles of road carriages, although they were generally made of iron of the finest quality.

Extract 3. Mr. Lowe stated that at the gas works under his direction wrought-iron fire bars, although more expensive, were generally preferred; a pan of water was kept beneath them, the steam from which speedily caused them to become magnetic; he had frequently seen these bars, when thrown down, break into three pieces with a crystallized fracture.

Extract 4 is from the "Engineer" some three and a half years ago. A paper was read by Mr. Peter Carmichael, in which he gave the following as a reply he got from the makers of two boilers he wrote about: "From experience the firm found that all qualities of iron got hard and brittle after the boilers had been at work more than a dozen years, more especially when exposed to the action of the fire, and that in the furnaces, even Lowmoor or Bowling iron becomes as brittle as common iron in that time, and great care has to be taken in making repairs to prevent plates from cracking. For this reason they thought sixteen to seventeen years a long enough period for a boiler to be in use, at a pressure of 40 to 45 lbs. to the square inch. If used for a longer period the pressure ought to be lowered." I must not omit to say that Mr. Carmichael says that the plates had become very brittle although made of Glasgow best iron for shell, and for flues Glasgow best scrap.

These extracts give us opinions of the different purposes for which iron is used. And they imply that the iron was good and fibrous, that the iron manufacturer was of known repute, etc. All this is very good for the iron-master, because it exonerates him from all blame, and in reality no blame can be attached to him if he has fulfilled the contract entered into between him and his customer. Now it is somewhat strange that not one of these extracts gives us any data, or proof to guide us in forming a reliable conclusion. Assuming that these gentlemen believed that the axles, the pins for the pump rods, or the crank pins, the grate bars, and the boiler plates were from well-known makers; that the axles did turn up nice and soft, showing a long turning, the pins forged well and turned up bright, the grate bars and the boiler plate were from best iron and best scrap, no man can say on looking at these finished articles that they were tough and fibrous, unless he had watched every working carefully, or had the adjacent scrap tested, and if he breaks the article he destroys it, and must replace it. However, the user has bought them, and these things must, and are, put to do duty. And when they have done duty, they have not all broken. No! for not one axle or crank pin in a thousand breaks, because they have become crystallized through vibration. Nor does the grate bar, because the steam has magnetized it; while the boiler plate becomes hard and brittle, only so far as its atoms have been disturbed after leaving the mill and previous to being riveted up. But if one of these axles, tires, rails, crank pins, etc., breaks, though only one in a thousand, it is put down to vibration, extreme cold, excessive heat or magnetism, by those people who endeavor to account for every phenomenon, but who rarely succeed in proving anything.

If you require proof of my assertions, I give you what I consider proof, and invite discussion, in the belief that something may be learned from it. I have seen axles worn out, some of them broken at the journals, because worn under original size, which could scarcely be broken in the middle; and after breaking, the fracture shows the build of the pile or faggot the axle was made from. Some part of the fracture being beautifully fibrous iron, the other part crystallized. If vibration causes crystallization, how is it each particular part of the pile has not become the same? Scores of axles were bought by a firm not far from here for old scrap; they could not be re-worked until they were cut into halves. The firm essayed to break them by pulling them up 16 ft. to 18 ft., and letting them fall on their middle across a piece of metal. This failed, with few exceptions. It was tried to break them by letting a ton weight drop upon them. This gave similar results, failing also; and had there been no other means of getting this very good scrap in half it would have been dear at a gift; therefore they were not brittle by vibration. The journal of an axle being the extreme end of the forging, gets too often more fire than it needs, and is therefore burnt at this part; this is the cause why some of the journals may be crystallized. I have seen thousands of tons of old rails cut up, some of which have been crystallized at one end, and fibrous at the other; some brittle throughout the entire length, and some fibrous; some in one fracture part fibrous and part crystallized, all clearly showing the manner in which the pile had been made up, proving to a demonstration that the rail-maker knew where to put the inferior iron when making the pile for the rail. Tires in like manner present the same appearance as rails; therefore they are not crystallized by vibration.

The grate bar extract is as flimsy as possible, for who would pay Lowmoor price for grate bars? No one. The user wants a cheap wrought iron, and he gets a brittle grate bar, which is continually undergoing expansion and contraction and burning, and these are the causes of grate bars being brittle, and not magnetism. Mr. S. M. Saxby, R. N., some few years ago found that imperfect welds and cracks could be detected by the magnet; this is very ingenious, but he could not make tough iron brittle by it.

The boiler-plate is rather different to the other classes of iron taken. Some people argue that boilers vibrate very much when working, consequently become crystallized. Mr. Carmichael only ventures an opinion on those plates that are exposed to heat. My opinion is this:—The plates, after leaving the manufacturer, and before being put in the boiler, are shaped to a required template, and just in proportion to the circle they are bent to, are the atoms of the plates disturbed by compression on the concave side and elongation on the convex side, sometimes to the extent of fracture. These fractures are so small at times as not to be visible to the naked eye; nevertheless they are there, and ultimately, by the continual expansion and contraction, the invisible becomes visible, and, unless the defective plate is repaired or taken out, may lead to something worse; not because the plate has become crystallized only so far as it has been compressed on the concave side, but because it would not stand bending to the desired form without injury.

There is another very important use iron and steel are put to, well worth our attention, and which I imagine will strengthen me in my conclusions, and that is the wire pit rope. That very flexible and ductile material, which is incessantly being bent backward and forward, continually in a state of tension and vibration, would not stand what is required of it for as many hours as it does months, if the numerous threads of wire comprising the rope were brought so close together as to form one compact bar.

The effects of extreme cold and frost on iron must not be omitted, for only two or three years ago, on the approach of winter, it was prophesied that the Bessemer rail would be doomed, inasmuch as it would become crystallized or cold short and break. Now, with all due respect to these theories on the causes of crystallization, I wish to affirm that neither vibration nor magnetizing by steam has any such effect on iron, and I will at once give you what I believe to be the causes of crystalline iron, and they are percussion or force of impact, compression or contraction, excessive heat or burning, and last, though not least, the practice of manufacturing finished iron from pig-metal that has been made from iron ores containing phosphorus or silicium.

Take these causes seriatim. Impact does not granulate unless the bar under experiment or accident is nicked with a set, or has some flaw in it to start from, *i. e.*, if the bar or plate is tough to commence with. A bar was shown which would not yield to the force of impact until nicked, but after being slightly cut all round, and receiving a good blow from a sledge hammer, the piece flew off. The bar was afterwards cut on one side, and then struck again with the same hammer, but instead of breaking off short and granular a beautiful fibre showed itself.

Again, in the case of armor plates, the force with which they appear to be struck should crystallize them, if percussion had the same effect under all circumstances. Compression or contraction is somewhat different, but is really a change brought about generally by mechanical agency. I have here a tough fibrous bar bent over in the form of a tuning fork, the outside fibres "give" and are elongated, while the inner fibres become so compressed as to burst and show crystals. Heating a bar hot and hammering it until it is black cold, is simply a bringing of the fibres closer together, causing like results. The threads of iron forming the wire rope are a sort of happy family. If any undue strain comes on one or two of them while passing over the pulley, the others give way and form a cushion to bed them in for the time being; their relation to each other is something like the strands forming a skein of thread. Not so with the fibres of a bar; for they would in a short time become compressed, and that causes crystallization. Thin sheet or iron for tinning would be of little use, if it was not annealed after leaving the rolls; being finished so cold when rolling, the skin is so compressed that on bending it would crack, but on putting the same in a furnace and heating to a red heat, it becomes very ductile, because the atoms of the iron through the effect of heat have become relieved and resumed their normal condition. On asking Mr. Mushet, the metallurgist, some few years ago, to explain the paradox I have here, the answer was, "When you anneal the sheet, if the annealing was long continued, you deprive it of carbon, therefore the annealed piece would contain less carbon than the piece you simply heated and then hardened in water." The thin iron before us was rolled from what is called puddled stock iron, and presuming Mr. Mushet's answer correct, this cold shortness is caused by the iron retaining its carbon; this wants proof by analysis; but this I can prove. The hard or cold short end is contracted, and becomes thinner than the soft end.

Some two years ago Mr. Brockbank, of Manchester, read a paper on the effect of cold and frost on iron, his theory, like many others, being that it caused iron to become brittle, and to corroborate his views he got several gentlemen to test iron for him at a time when the thermometer indicated below 32 deg. Fah. Several gentlemen opposed his theory, and the result of the experiments did not carry with them convincing proofs. A learned professor taking the lead in the opposition, afterwards got a dozen darning needles, and a lot of garden nails (cast iron), a most unsatisfactory material to obtain anything like certain results from; however, he found that the needles took a greater tensile strain at 12 deg. than they did at 55 deg.; the garden nails gave similar results; his general conclusions were that frost does not make either cast or wrought iron or steel brittle. Mr. W. H. Johnson, of Bowdon, tested a No. 4 charcoal rod, and he found that on the test-piece being twisted slowly while surrounded with salt and snow, it stood 19½ twists; the adjacent 6 in. at 40 deg. stood only 15 twists. These and other like experiments tend to prove what I contend for, that iron will bear a greater tensile strain the colder it is, but that its resistance to the force of impact is in ratio weaker. Why is this? for neither of these gentlemen tells us. Because the atoms of the iron are brought closer together by the contracting influence of extreme cold. The specific gravity is greater. It assumes more and more the texture of steel, which every one knows will not bear a heavy sudden blow without breaking, but try and pull its atoms asunder, *i. e.*, try its tensile properties, and you find it something astonishing.

Sir C. Lyell, in his "Principles of Geology," tells us that fine-grained granite expanded with 1 deg. Fah. at the rate of 4825 ten thousand millionths, and red sandstone 9532 ten thousand millionths, or about twice as much as granite. Professor Joule worked out the mechanical equivalent of heat, proved that a weight of 772 lbs. falling through a space of 1 ft. was able to raise a pound of water 1 deg. Fah. If measurements half so nice as these were made on iron, it would be found that for every degree of heat lost, the iron shrank, and in exact proportion as the atoms are contracted so is its tenacity improved, and its resistance to the force of impact impaired.

Excessive heat or burning will crystallize iron, and cause it to break short when cold. So much was this theory relied upon a few years ago, that it was looked upon as impossible to make a large forging or finish any large mass without it being crystallized, owing to the lengthened time it must be in the furnace before it can be brought to a welding heat. This idea has exploded now, for with careful workmanship and a good fibrous iron to commence with, a tenacious plate has and still is being made in Sheffield for armor plating.

We come now to the primary cause of crystallization, which is the manufacture of finished iron from pig metal that has been produced from ores containing phosphorus and silicium. It is as impossible for us to produce the same quantity of iron from the oolitic or silicious ores as is produced from the hæmatite ores, as it was for the old alchemists to find the stone they dreamed of, which was to convert all base metals into gold. Hence, for the consumer of iron to expect the same article from different districts is a mistake, unless the native ore is disused and others imported, and this adds to the cost.

Nearly all manufacturing districts have their own specialties, cost invariably being in proportion to the quality. And many users of iron finding the cheap article suits their purpose, the manufacturer taxes his skill to avoid this cold short crystalline property. By judiciously mixing the pigs for the puddling process he attains his purpose, and produces for his customer the suitable common crown iron of commerce. This iron eventually becomes so much scrap, and is brought up for reworking into shafts and other large forgings; but the fibres that were developed by the first and second process are lost in this, its third reworking, and the metal becomes crystalline. It is generally expected that by repeated reworkings, all iron improves; this is not the case.

An experiment is recorded in "Metals and their Alloys," where a tough fibrous puddled bar was taken and cut down and piled 5 layers high and rolled into a bar; a test piece was taken from this, the remainder was piled as before, and so continued, until the iron had undergone 12 workings; the result was, it increased in tenacity from a tensile strain of 43,904 lbs. on the puddled bar, to 61,824 lbs. at the sixth working. After this the descent was in a similar ratio to the previous increase, and at the twelfth test it gave again 43,904 lbs. This instance tends to prove that if tough fibrous puddled bar to commence with will not improve only to the sixth working, weak or partly crystallized puddled iron would show depreciation much sooner.

A few words on the utility of iron, and I have done. I ask you to look on that monument of engineering skill that spans the Menai Straits; on that diamond-looking structure at Sydenham, the one stiff and inelegant, the other full of graceful lines, tints, and combinations, and fancy the impetus given to the use of iron by such works.

Think of the wrought guns capable of throwing shot nearly 100 lbs. weight, and the war ships with their sides clothed with plates of iron 14 in. thick to receive them. See the minute indicators on your watch face, and the spider's-web-like hair spring that regulates them. And of what use would have been the electric telegraph without the wire rod?—The various experiments and brilliant researches of Galvani, Volta, Arago, Ampiere, Oersted, Faraday, Wheatstone, and others, on electricity and magnetism, coupled with the labors of Cooke and Morse, who brought to a successful issue the means by which a thought may literally, in the words of the poet, "be wafted from Indus to the pole?" When I ponder these things, I am ready to exclaim, "Upon my word, there's nothing like iron."

FRENCH ARTILLERY EXPERIMENTS.

From "Iron."

The results of a second series of very exact experimental investigations made at Bourges, to determine the relative values of long and of short rifle bearings in ordnance have just been made public in France. No programme could have been conceived on more exact scientific principles, to measure the respective effects of fully supporting a projectile along the whole length of its cylindrical body, and of balancing it upon two nearly central points.

To test this point, nine-pound shells carefully turned, were procured from Woolwich Arsenal, with the usual balancing studs in them. After these had been fired at Bourges, from a Woolwich-made gun, the studs were removed and narrow slots were cut into their sides, and they were again fired, but from a Vavasseur ribbed gun, in which they were supported along the whole length of the body. Beyond the differences of rifling, the guns were practically identical, both being tubed with Frith's steel. Not only were the same shells used in both guns, but they were fired on the same days, under the same state of the atmosphere, with similar charges of English made R. L. G. powder of 1.67 density taken from the same barrels. The French officials appear to have taken extraordinary care that no disturbing element should vitiate the experiments for comparative purposes.

The tables published in the "Revue d'Artillerie" show that when the same Woolwich-made shell was supported on long iron rib bearings, the results were at every point superior to its performances in its original state when balanced in unstable equilibrium upon two studs. This superiority increased steadily as the range and elevation advanced, and is shown not only in the initial velocity and the distance attained, but, as we should have expected, in accuracy of flight.

A more crucial test of the relative values of a most important point in rifling for heavy ordnance could not well have been devised, and the scientific accuracy with which the test was applied, makes the tabulated results an invaluable aid to inquiring scientific artillerists. The real gain is not, however, in the elements shown in the tables, but in the endurance both of the gun and of the projectile, which are indicated by the figures; for it is obvious that where all else is equal, low velocity, high powder-pressures, and less accurate flight, are all indications of work wasted within the gun upon its walls and upon those of the projectile. The constant repetition of these extra strains subtract from the endurance, as every projectile issued from a Woolwich balancing gun shows, and as the guns themselves too often testify. At a range of 2,000 metres, the mean gain thus obtained for the same shell under similar conditions, by supporting it on long iron bearings, was 10 min. of elevation, .10 metres less error in range, 1.89 metres less error in direction, .06 metres less height of trajectory, and .15 sec. less time of flight. Whilst at 5,000 metres, the mean gain to the same shell was 1 min. 23 sec. less elevation, 2.90 metres less error in range, 8.25 metres less error in direction, 4.50 metres less height of trajectory, and 1.8 seconds less time of flight.

Thus it will be seen that at every point of accuracy and range, the Woolwich shell, when modified by Messrs. Vavasseur, and the substitution of long bearings for the balancing studs, had greatly the advantage over its former self. Ten different rifled guns appear to have been under trial at Bourges at the same time, and the palm for accuracy was given to the one which fired "les obus de Woolwich modifiés," *i. e.*, with a long iron bearing rib; the original Woolwich studded shell being third on this point; the second place being occupied by the breech-loading "Canon de 4 prussien," and the fourth by the "Canon de 8 francais," a muzzle-loader.

Great importance attaches to these experiments, not so much as it affects field artillery, but as it bears upon the endurance and the performances of heavy ordnance. The heavier the projectile to be fired, the less enduring and the less powerful, relatively, must be the gun, so long as the proportion of the projectile which touches the walls of the gun is nearly the same, whether it be a shot of 100 or of 700 lbs. weight.

A fifty-ton gun will not then have to be devised to do the work of a thirty-five ton gun.

PROPOSED PIERCEMENT OF MONT ST. BERNARD.

From "Iron."

Under the title "Alpine Railways" (see "Iron," Sept. 6th, p. 309), we gave a general sketch of the proposed plan for carrying a railway across Mont St. Bernard; the projectors have since continued the subject at great length, and we shall select from their voluminous documents a few extracts of general interest. The projected line starts from the town of Martigny, which is a station on the Simplon line, starting from Bouveret on the shore of the Lake of Geneva, and which is now advertised for sale by auction by the Swiss authorities, passes by the valley of the Rhone, and reaches the northern flank of Mont Chemin at Charrat; it then passes along the southern flank of the Borgeau, enters the valley of Bagne opposite Sembrancher, and follows the same slope of the mountain as far as Champsee, where it crosses the valley, and turns the northern flank of Mont Larcey, proceeds as far as Sembrancher, and then enters the principal valley of Entremont, and passes along the right side by Chamoille, La Rozière, Reppay, Fontaines-Dessus, Liddes, Alève, and St. Pierre, gains the plain of Prox, where commences the northern end of the tunnel, which debouches at the same altitude in the valley of Menouve. From this latter point the line turns the flank of the hill above Etroubles and St. Oyen, inclining towards St. Remy, and traverses the Combe der Bosses till beyond Chuille, where it traverses the valley of the Bosses, and returns on the right side to Etroubles. From this place it runs nearly parallel to the road from Aosse to St. Remy, and descends by Guiod and Arpouille; it then enters the valley of the Doire; passes above Ponte d'Aviso and Clut, and traversing the river near Villeneuve, arrives at Aoste by the right side of that valley. The total length of the line is nearly 124 kilometres (77 miles English).

The most important features of the plan are the following:—At Borgeau a curved tunnel of 500 metres; beyond Bovernier, two tunnels, one of 100, the other of 300 metres, the mouth of the latter being in face of the old Trappist monastery; between Sembrancher and Vollèges, a tunnel 250 metres long; another of 150 metres, in the side of Mont Larcey; another of 500 metres under Comcure; proceeding on to St. Pierre it enters a tunnel of 150 metres. At an altitude of 18J4 metres at the foot of the plain of Prox commences the great tunnel which carries the line into Italian territory; this tunnel is 5,800 metres in length, and lies beneath the Col de Menouve; over the 2,400 metres on the Swiss side the ascent is 0.0048; then follows a level distance of 1,100 metres, and a descent of 2,300 metres on the south side, with an incline of 0.005.

It is proposed to construct this tunnel in four sections, by means of side galleries, so that the work may be completed in three or four years. These working galleries will remain open afterwards for ventilation and other uses. A peculiar feature is that it is proposed to form a station within this tunnel by widening 600 metres of the level, central portion; one of the objects which has led to this singular plan is, that possibly for economy's sake two light trains which had made the ascent separately might be joined together for the descent on the other side. It is also argued that with such an arrangement many tourists would be glad in the summer season to attain the summits of the group of the Grand St. Bernard by the inclined passages already referred to, and at the mouths of which stations for refreshment, and even for lodging, might be established.

The principal works, after quitting the great tunnel, on the Italian side are:—A tunnel below St. Remy of 430 metres; ten kilometres further on a second tunnel 300 metres long, and a third at the Gorge de Cluze 200 metres. The declivity on the Italian side is equal to 0.022. The minimum radius employed for the curves is 300 metres, and this is seldom employed. The average inclination of the line is 0.021, and this may possibly be reduced by two or three millimetres.

The soil over and through which the work passes supplies all the necessary materials, so that great cost of transport will be avoided. This is asserted to be the case on both sides; moreover, there exist great masses of anthracite at Liddes, Fontaine-Dessus, and Planardo, for fuel, while the forests afford timber for building purposes.

The total cost of this work is estimated at 61,510,000f., or £2,460,400, the cost of the great tunnel being set down at 17,000,000f., or more than one-fourth of the sum total.

The connection of Aoste with the Italian lines of railway at Ivrée and Santhia is set down at a further sum of 28,500,000f., making a grand total of 90,000,000.

The projectors devote two long chapters to the question of traffic and consequent profits, but it is not necessary to enter upon this part of the subject, at least at present.

The "Monitore delle Trade Ferrate" says that the Prefect of Turin has made a report on this project to the Provincial Council of Turin, expressing a strong opinion in favor of it, and declaring it to be his opinion that the Government and the Parliament, seeing the consequence of such a line to the Province of Turin, will be inclined to carry it into execution at any cost.

THE CHEMICAL CONSTITUTION OF STEEL.

By ADOLPH OTT.

From "Iron Age."

There is still considerable diversity of opinion among scientific metallurgists regarding the chemical constitution of steel. What elements belong essentially to its composition and which not; in what manner the several substances are combined with each other, and in which form of combination they effect the production of steel; all these and other questions have given rise to lively discussions, especially among French chemists, and are yet to be definitively decided. Chemical analyses, as well as the formation of steel from wrought and pig iron, indicate that iron and carbon must be considered as its most essential ingredients; but, besides, there are found in it in smaller quantities various elements of an electro-positive and electro-negative nature, such as silicon, sulphur, phosphorus, chromium, arsenic, copper, manganese, wolfram, titanium, etc., which partly originate from the pig iron or have been added to improve the quality of the final product. Hence, steel consists as little as pig iron of a pure carbonized iron, but contains also smaller quantities of various other chemical combinations. These secondary ingredients exert either a perceptibly injurious or favorable influence upon its texture and properties of hardness, strength, weldability, elasticity, etc.; but as they vary according to nature and quantities, and are sometimes scarcely to be detected, or are not present at all, without the steel losing its character, as is the case, however, with an increase or decrease of the carbon, we are not entitled to consider these bodies of equal importance as the carburets of iron.

In opposition to these views, Fremy maintains that steel is a compound of carbon, nitrogen and iron, in which carbon as well as nitrogen can be replaced by certain other bodies, so that, as already maintained by Chevreul, there would be many kinds of steel of different compositions, and among them such as contain no carbon. Concerning this hypothesis, however, we do not possess as yet any reliable analytical proofs.

The quantity of carbon necessary to produce steel varies between 0.65 and 2.3 per cent. When containing less than 0.65 per cent. the product cannot be hardened any more, and then constitutes wrought iron; while, on the other hand, it becomes pig iron when exceeding 2.3 per cent. carbon. Yet these figures have rather a theoretical than a practical significance, as the amount of carbon of the ordinary kinds of steel varies between narrower limits, viz., between 0.7 and 1.9 per cent. Karsten found in crude and cast steel from 0.9 to 1.9 per cent., in cementation steel never more than 1.75 per cent. According to Mayrhofer, hard crude and cast steel contain 1.84 per cent.; cast and refined steel, too brittle for wires and springs, was found to contain from 1.58 to 1.11 per cent.; elastic cast and refined steel from 1.11 to 0.70 per cent.; soft puddling steel and steely or fine grained iron 0.62 carbon.

The carbon is either chemically bound or separated to a smaller part as graphite. Gurlt considers steel as a mixture of metallic iron and iron containing $\frac{1}{8}$ of carbon (Fe_8C); Tunner, as iron with the compound Fe_4C; Lohage, starting from the supposition that the molecule of carbon is a regular octahedron, considers it probable that by juxtaposition of iron molecules to the corresponding faces, or (according to the law of formation of the tetrahedron) to the alternate surfaces of the carbon octahedron two different series of iron carburets may be formed. Those with a stable equilibrium of the tetrahedric molecules, Fe_8 C, Fe_{16} C, Fe_{24} C, represent compounds which can be hardened, while those with with unstable equilibrium of the octahedric molecules, Fe_4 C, Fe_{12} C, Fe_{20} C, represent compounds that cannot be hardened.

The hardening of steel and the conversion of gray pig into white pig iron by rapid cooling is supposed to be owing to the fact that the decomposition of the compounds liable to be hardened is prevented.

Mayrhofer established the following chemical formulæ for various brands of steel:

		Fe.	C.
Hard crude and cast steel..............	Fe_6 C	98.16	1.84
Cast and refined steel, not well applicable to springs and wires, owing to its brittleness	Fe_7 C	98.42	1.58
	Fe_8 C	98.61	1.39
	Fe_9 C	98.77	1.23
	Fe_{10} C	98.89	1.11
	Fe_{11} C	98.99	1.01
Cast and refined steel, well applicable to springs and wires, owing to elasticity.....	Fe_{12} C	99.06	0.94
	Fe_{13} C	99.14	0,86
	Fe_{14} C	99.20	0.80
	Fe_{15} C	99.25	0,75
	Fe_{16} C	99.30	0.70
	Fe_{17} C	99.34	0.66
Soft puddling steel and steely iron...	Fe_{18} C	99.38	0.62

Silicium forms a regular constituent of steel, though occurring only in very small quantities. According to Schafhautl, it is combined with the carbon to carbide of silicium, and every good steel, in order to be liable to be hardened, should contain a certain amount of it. But, if the congruity of silicium and carbon with regard to their crystalline forms, as established by recent researches, is considered, as well as their affinity to the metals, a combination of both elements in steel has little probability, and it must rather be supposed that they replace each other in steel as well as in pig iron. According to all the facts known, it is generally agreed upon that silicium imparts greater hardness and brittleness to steel, diminishing also its strength when present in about 0.05 per cent. and more. The pure compounds of silicium and iron being yet insufficiently known, and since the observations on this subject contradict each other, it is yet doubtful whether silicium is capable of exerting such an influence. I would remark that the compound of silicium and iron prepared by Hahn, with 10, 20 and 31 per cent. silicium, was exceedingly hard and brittle, while Berzelius, on the other hand, mentions that a silicium iron which, on dissolving in muriatic acid, yielded 19 per cent. silicic acid (corresponding to 8.8 per cent. silicium), was soft and could be hammered into thin foliæ.

Sulphur and phosphorus exert on steel essentially the same influence as on wrought iron, producing either red-short or cold-short steel. Eggertz found in good kinds of steel only from 0 to 0.012 per cent. sulphur; of phosphorus from 0.01 to 0.02 per cent. Both contribute to the weldability. Phosphorus imparts to it a fine, brilliant white grain and the property to attain a high polish.

Arsenic, according to Schafhautl, in small quantities, renders steel fine-grained, hard and solid; in larger quantities, red-short. In hammering the best English cast-steel, prepared from Dannemora iron, he obseved sometimes a very strong arsenical smell; he therefore ascribes the superior quality of Swedish iron partly to a certain amount of arsenic iron.

Regarding the presence of nitrogen in steel, on which Fremy lays especial stress, it ought to be stated that the quantities found are so small that it is scarcely possible that it could take an essential part in the constitution of steel. Marchaud, by his investigations, arrives at the conclusion that it is not conclusively proven that cast iron and steel contain nitrogen. Bouis, by conducting dried hydrogen over glowing steel, found as maximum in wootz steel 0.00672 per cent. nitrogen, and Boussingault, by another method, in various specimens of cast steel, 0.007 per cent., 0.042 per cent, and 0.057 per cent.

Copper acts destrimental, and, according to Stengel, as well as Eggertz, a fraction of a few tenths of a per cent. renders steel cold-short. The latter found in Dannemora iron, which is especially valued for the making of steel, only 0.03 per cent., and in various other varieties of steel 0.2 per cent.

Chromium is said to exert an exceedingly valuable influence on steel, but no analyses of such steel are known to me.

Manganese, wolfram, titanium, aluminium, nickel, rhodium, osmium-iridium, platina and silver are also said to improve steel. There is no doubt that some of these substances, when passing in a remarkable quantity into steel, exert such an influence, but others, which either are only met in traces, or not at all, have either only an indirect purifying effect, or are entirely useless. It is often the case that people ascribe to their presence what has only been a consequence of remelting and of a further working of the steel. Of the last named metals the manganese is the most important.

According to all observations manganiferous ores, especially spathic ores and pig iron produced therefrom, are most suitable for the manufacture of steel, and in fining, puddling in the Bessemer process, and in remelting steel, manganiferous fluxes render excellent service. It should be observed, however, that the influence exerted by the manganese is chiefly an indirect one. While, on the one hand, it passes mostly into the slag, on account of its property to be easily oxidized, and often only in traces into the iron itself, it retards, on the other hand, decarbonization, favors essentially the separation of silicium, sulphur, and partly phosphorus, and produces a readily fusing slag, which attacks the walls of the furnaces but little, protects the steel from rapid oxidation, thus rendering the steel more solid and of easier weldability. The latter fact is very important, as steel must be worked at a lower temperature than wrought iron. The most suitable form in which manganese can be used are manganiferous pig iron (spiegeleisen) carbide of manganese, or an alloy of manganese and iron. Added in the oxidized state, as black oxide of manganese, it soon forms a silicate or protoxide of manganese, and acts then, decarbonizing by yielding oxygen.

Wolfram alloys with iron, and passes therefore into steel, as proven by the analyses of Sauerwein, Siewert, and Rammelsberg, who found in the respective kinds an amount of from 0.9 to 7.43 per cent. The Duke of Luynes, as early as 1844, used wolfram for the manufacture of Damascus steel, and called attention to its occurrence in the celebrated blades of Damascus ; later (in 1855) it was applied in Austria, England, and France. Wolfram steel distinguishes itself by a very dense texture and a conchoidal silky fracture, by great hardness and strength, and can easily be welded with wrought iron ; according to Appelbaum, it requires a greater heat than English cast steel. Rossler found it less suited for mint stamps than Krupp's cast steel, owing to the readiness with which it cracked. However, this steel has not found the general application it was supposed to attain, which may partly be due to its higher price, partly to the difficulty of treating it.

Mushet recommended titanium in order to impart to steel greater hardness and other superior qualities, by adding titaniferous ores in the high furnace, cupola or during puddling. A very suitable iron is thus obtained.

Stoddard and Faraday fused steel with silver, platina, osmium-iridium, rhodium, nickel, aluminum, as formerly Berthion did with chromium. Concerning rhodium steel, it is stated that it possesses extraordinary hardness. Platina steel is said to attain high polish, and nickel steel (meteor steel) is stated to attain the finest damascening. Those investigators ascribe the superior qualities of the Indian wootz steel to a small amount of aluminum, of which Karsten found only doubtful traces and Henry none at all. Gruner and Lan assert, on the contrary, that aluminum acts injuriously, and they call attention to the fact that for the Bessemer process those ores are most suitable which contain the least clay. Of silver only very small quantities pass into the steel (0.2 per cent., according to Faraday and Stoddard). By adding 1.500 silver to cast steel Elsner could not discover any change or improvement, except that produced by remelting. All these often praised varieties of steel have as yet not attained the importance which was ascribed to them.

STORAGE AND DISTRIBUTION OF WATER IN INDIA.

(*Continued from page 182*)

Mr. J. H. Latham said that his personal experience of the district in India embraced by Mr. Gordon's Paper enabled him generally to corroborate the facts stated. The old Hindoo system of village tanks must gradually come to an end, owing to the natural and inevitable silting up of their shallow beds, unless fresh tanks were continually added, as of old, to supply the place of such as became inefficient for irrigation from this cause. Mr. Latham quoted Col. Playfair, R. E., to show that, in the Deccan and South Mahratta country, the same difficulty existed in the way of this renewal as existed in the Madras Presidency, viz., that village tanks, as a rule, were not paying works. On this account Government could not fairly spend public money upon them, for the benefit of the local villages, nor would private speculators build them. As a fact, charitable persons did not any longer come forward to build them. The old system of village tank irrigation was therefore dwindling away, and any useful system meant to replace it must involve, to a certain extent, novelty. The Madras Government seemed especially to have appreciated this, and had proved the most speculative and successful of the Indian Governments. Permanent irrigation had been secured on the coast by their well-known works at the heads of the river deltas, of which the most important on the Cauvery, Kristna, and Godavery, were calculated to pay from 23 per cent. to 60 per cent.; and by the purchase of the Orissa works from a private company, which were calculated to pay this year 12 per cent. Again, in the Neilgherry hills, there seemed to be no reason why their bold attempt to construct a tank 140 ft. deep by the silting process should not ultimately prove successful. But these plans were not applicable for up-country irrigation, for which the system most advocated, amongst others by Mr. Gordon and Col. Playfair, was that of river channels, combined with reservoirs for storing the water from the monsoon rains. Since the commercial success of such schemes was of primary importance, any information bearing on the actual cost of the works, or on the commercial value of water provided by them, would be interesting. A most important matter affecting the cost of the works was the provision of an adequate escape for surplus water, the quantity of which was, in some schemes now proposed, very large, necessarily delivered at a great height, and requiring costly works. Adopting the formula

$$D = C\,n^{\frac{2}{3}},$$

where D was the quantity of water for which escape was required for a drainage from n square miles of country, and C some constant; then, taking D in cubic yards per hour, in the designs for the Ekrooka tank, near Sholapoor, under construction by the Bombay Government,

$$D = 61{,}523\,n^{\frac{2}{3}}.$$

On the Ganges and Godavery works it was stated that escape would be provided for

$$D = 75{,}000\,n^{\frac{2}{3}};$$

and on the Madras Irrigation and Canal Company's works Mr. Latham was providing escape sufficient for

$$D = 100{,}000\,n^{\frac{2}{3}}.$$

These differences showed how important it still was to have more information on the subject.

The value of the water stored depended primarily upon the area of irrigated crop for which a given quantity of water sufficed. About this great differences also existed. The supply of each cubic yard of water per hour was taken in the Ekrooka scheme to suffice for $\frac{9}{10}$ of an acre for a year's irrigation, and for $1\frac{1}{8}$ acre for crops grown during the wet months. In the Lakh project on the Paihra, as sufficient for $\frac{3}{4}$ acre and $\frac{8}{9}$ acre, respectively, for these crops; and by the Madras Government, as sufficient for $\frac{1}{2}$ an acre only of either crop. The experience of irrigation on the Soonkêsala canal of the Madras Irrigation and Canal Company was too brief to give a definite result, but indicated that, where due care was used to prevent waste, the Bombay practice was nearer the truth than the Madras. That the Madras estimate was too low seemed also indicated by Col. Baird Smith's estimate, that a cubic yard an hour sufficed for $1\frac{1}{3}$ acre of irrigation in India. The water-rate to be charged per acre would, of course, be different for different districts, and was a mere question of the value of produce in the locality. Perhaps Mr. Gordon could give more definite information on the subject of escapes, and on the irrigating power of water in India.

Since the amount of drainage water to be provided for in these reservoirs affected their cost seriously, he would give a few particulars of the rainfall in Southern India during the time he was there. Excepting an extraordinary fall, to which he would refer presently, the greatest depth registered at Kurnool in any one month in the ten years, 1862–71, was 13.77 in., in September, 1862; the greatest depth in one day being 4 in., on the night of the 24th of that month. The only other occasions on which a total depth of 7 in. fell in a month were in August, 1865, 7.73 in.; and in August, 1868, 7.35 in. Since January, 1868, when the Kurnool Observatory was established, a depth of rain exceeding 2 in. in 24 hours was registered on three occasions, in no case reaching 3 in. But on the exceptional night of the 6th of August, 1870, an extraordinary storm from the south-west occurred, and 12.01 in. of rain fell in twelve hours. At a distance of 13 miles west of Kurnool, the storm was felt in the daytime of the 7th, after rain had almost ceased at Kurnool, and only 7.22 in. fell. At a distance of 30 miles east of Kurnool, an unusually heavy rain occurred during the night of the 6th. This proved that ten years' experience of one place was quite inadequate to determine the frequency of such excessive falls. Two other storms deserved notice; one at Gooty, and the other at Tadamurri, adjacent talooks in the Bellary District, in the autumn of 1864, when a depth of above 8 in. of rain fell in one night. The other was a short storm, which he gauged, at Böanassey, on the 72d mile of the canal, when for thirteen minutes rain fell at the rate of 3¾ in. an hour.

The interests of the Canal Company had hitherto required that water should be given to the village cultivators in excess of what they used for cultivation. As to observing an experimental patch of ground, there were insuperable difficulties in the way; for if the patch were isolated the water percolated through the soil and irrigated the surface for yards around, besides passing away through the subsoil. On the other hand, if the patch were surrounded by wet cultivation, the result could not be trusted, so easy was it to transfer water from one field to another surreptitiously; and if the result were trustworthy it would not give the average requirements for cultivation. The only proper observation would be to see how much water per hour per acre was actually used—when it was served out without waste; and that he had not been able to ascertain.

Colonel J. T. Smith said, as far as he could make out the Table on which the results given in the Paper were founded, there was one important element neglected, viz., that half the value of the produce was taken by the Government in assessment. The results of commercial speculation depended upon, first, what was paid for an article, and, secondly, upon what it could be sold for. To begin with the sale of the water, he had not been able to make out how it was deduced that £1 1s. per acre irrigated was the value; but the value so calculated was not important, for when discussing a commercial speculation connected with a concession from the Government, the Company was bound to accept the terms of the concession, and the Government concession of the privilege of storing water in South India was connected with a condition to sell it at the rate of 12s. per acre irrigated. Therefore he conceived the real commercial result ought to be based upon the 12s. per acre, and it would mislead the public if they were induced to believe that a return of 46 per cent. was to be obtained by selling the water at a guinea when there was actually no power to do so. He, therefore, concluded that the results ought to be based upon 12s. per acre.*

He now came to the cost of the water. He thought the Author had acted with great impartiality in the statements of cost, yet he could not agree with the results. The calculation was based upon an average reservoir, able to store water at the rate of 4,250 cubic yards per £1. That was an imaginary reservoir; but a description was more particularly given of one reservoir which was proposed to be immediately restored, viz, the Mudduk Masoor tank. He would say with regard to that, as well as with regard to the statement of past profit derived from Government irrigation works, that it was one thing to construct a work, and another thing to take a work already constructed, and simply out of order. If he brought forward a project for taking up a large number of houses out of repair, and showed that by putting them into good order he could make 23 per cent. by it, the scheme would appear very attractive; but the question would arise—who would give so valuable a concession? The Government, as possessors of these old tanks, had little to do to put them in order, and consequently made very large profits. It was stated that the Mudduk Masoor reservoir was about 40 square miles in superficial area when full; and that it con-

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* The Author guarded his statements by the express provision that the actual values were to be realized. but there was no such qualification in the second conclusion submitted to the meeting; and although it is quite possible that an increase in the water-rate might hereafter be allowed, yet such an increase ought not to be assumed in stating the present value of a mercantile speculation.—J. T. S.

tained 1,400,000,000 cubic yards of water. It was proposed to lower the dam from 90 or 108 ft. height to about 70 ft., and then the area would be about 24 square miles. The Author, by experiments on the spot, found that an average monsoon rainfall yielded about 668,000,000 cubic yards of water; consequently he proposed to provide a reservoir which would contain a little short of that, viz., 644,000,000 cubic yards, which would be the capacity of the Masoor reservoir with a dam 70 ft. high. Upon this it might be observed that unless the monsoons were of great uniformity, it was not sufficient to provide reservoirs equal to the average expected; they ought to be capable of holding the maximum as well as the minimum rainfall. The question, therefore, arose, whether the district was one in which the seasons were uniform, or fluctuating.

He had the following reason to believe the seasons were extremely fluctuating. It so happened that the Company who proposed to construct this reservoir suggested another in the same neighborhood, called the Maury tank. The Chief Engineer sent home a report, founded upon observations, the result of which showed that there was abundance of water to fill the tank, and it was resolved to make application to the Government for it. But the Government hesitated to grant the concession, on the ground, partly, that the supply of water was insignificant compared with what was estimated, and partly because it was not more than the country required, and they therefore finally resolved to keep it for the use of the inhabitants. He had also been informed privately, but on good authority, that a similar hesitation was now felt as to granting the concession of the Masoor tank, and for the same reasons, namely, that the supply of water was much less than was supposed, and not more than was required for existing demands.

Now he did not attribute these different estimates of the probable rainfall to errors of observation on the part of the various officers who made them, but to the fact that they were made at different times, and that the fall of rain in the district was very uncertain. Hence if the parties constructing such reservoirs made their calculations on the ground of storing the average monsoon rainfall, they must have a larger tank than the average monsoon rainfall would fill. Calculating without this would tell in one of two ways. Either the tank would cost more from building it larger, or there would be less water on the average than was anticipated; and on those grounds he thought some deductions ought to be made from the Author's estimate of the value of the produce of these tanks.

The next point was the evaporation from the tank. The specimen or representative tank was supposed to contain 4,250 cubic yards for every £1 sterling laid out upon it; which, allowing for interest on the money during construction, was calculated to yield 340 cubic yards per rupee; but it was necessary to modify this calculation, because it was one thing to have the water in the tank, and another to have it on the land.

Reverting to the Mudduk Masoor tank of 24 square miles area, and 640,000,000 cubic yards capacity, the Author had estimated the evaporation during four months from that tank while it was being emptied, and his calculations had been made upon proper data, which corresponded with experiments carried out by order of the Madras Government, whereby it was deduced that in the middle of the tank the evaporation was about one-third of an inch per day, or 10 in. per month. This result was, however, subject to a deduction of one-half, inasmuch as there was a reduction of surface from 24 square miles at the beginning of the discharge to a greatly diminished surface at the end. That through the evaporation down to 20 in. in the four months, over a surface of 24 square miles, and amounted to 40,000,000 cubic yards, or 6⅔ per cent. of the 640,000,000 cubic yards which the Masoor tank was to hold. Now, 6⅔ per cent. during the four months was equal to 20 per cent. during the year. For it must be noted that, although it was quite sufficient to calculate the evaporation from the surface of the reservoir during the months of discharge only, if the object was, from a given quntity at the beginning of the discharge, to determine the quantity which left the reservoir, yet the case was different when, with a given average monsoon rainfall, it was intended to ascertain the loss by evaporation during the time of its collection in the reservoir, its preservation there, and also its discharge. For this purpose the evaporation for the whole year must be taken into account, at an average of half the surface during collection and discharge, and during the remainder as for the whole surface. Hence the loss for the whole year would be 20 per cent. without reckoning the full rate during the interval of repose.* And here he would mention that when the experiments were made on which the rule of the irrigation department was founded, viz., that one-third of an inch per day was evaporated from the middle of a large tank, the gentleman who had charge of the experiments reported at the end of the season that $\frac{5}{8}$ of what had left the tank left by evaporation, and only $\frac{3}{8}$ had gone on the land; that was, $62\frac{1}{2}$ per cent. was evaporated, and only $37\frac{1}{2}$ per cent. had gone on to the land; the field referred to being in the immediate vicinity of the tank, so that there could not have been a length of more than from 10 to 20 miles of irrigation channels.

The next question to be considered was that the water let out of the Masoor tank did not irrigate the fields immediately, but went down the bed of a river for 200 miles. He believed the bed was in some places rocky, and in others sandy and absorbent. Thus the water was in motion for 200 miles before it reached the irrigation canal, and an allowance must be made for evaporation and absorption. After reaching the head sluices the water had, on the average, 100 miles of main canal to traverse, and that canal was very leaky. There was a great deal of loss by leakage, not, however, owing to any fault of the Engineers, for they had done their duty perfectly. But it was leaky, partly owing to the extreme badness of the soil, and partly because, owing to financial considerations, it was thought advisable to let it remain as it was for the present, as it would have required a considerable expenditure of money to have made those banks tight; and it was thought better to postpone that expense till the water was more valuable than it would be for the first few years. In addition to the distance already traversed, there were between 300 and 400 miles of distributing channels finished, which might possibly be increased to 500 or 600 miles before they were all completed.† He would prefer that others should judge what was the proper allowance to be made for the losses referred to—first, by evaporation in the reservoir; secondly, in the bed of the river; thirdly, by leakage and evaporation in the main canal; and fourthly in the distributing channels.

In estimating a scheme of this kind, and calculating the financial results, it was proper to be on the safe side. The Government decided that 2 cubic yards per hour for each acre was necessary; but he observed that Mr. Gordon had calculated 5,000 cubic yards per acre only. He thought it should be 6,000 cubic yards. The average time of cultivation was about 130 days, and 2 cubic yards per hour per acre for 130 days was more than 6,000 cubic yards. Again, the mere evaporation alone, from the surface, at the rate he had stated, namely $\frac{1}{3}$ in. per day, would come to 8,000 cubic yards for the six months, and more than 5,800 cubic yards for 130 days; and hence, taking also into consideration absorption and other losses, he thought 6,000 cubic yards was the least that ought to be allowed for.

To recapitulate his remarks respecting the formation of the tanks, Mr. Gordon's estimate, after allowing for interest during construction, was 340 cubic yards per rupee. Now he had given reasons for thinking there ought to be an increase in that estimate, or, in other words, a diminution in the number of cubic yards stored per rupee. If, for instance, the Masoor dam were built of the full size, to secure the whole monsoon rainfall in every year, it would cost double the money estimated by the Author, and instead of 960 cubic yards per rupee, there would only be 480 cubic yards. In the same way, in regard to the specimen tank, instead of 340 cubic yards per rupee, there ought to be much less, if the whole rainfall were calculated. As he wished to take a most moderate view of the case, he would only strike off the 40 cubic yards from the 340, leaving the estimate at 300 cubic yards per rupee. But this did not represent the quantity actually put on the field; and, in his opinion, if the Madras Irrigation and Canal Company got one half of the water upon the fields, they would do very well. In that case they would have 150 cubic yards per rupee on the field, and the 6,000 cubic yards required for the irrigation of each acre would cost Rs. 40, for which they would receive Rs. 6 return. Now Rs. 6 for every Rs. 40 amounted to

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* Owing to a strange clerical error, the Author had omitted to make the deduction of 12 per cent. which he allowed, so that the £1 9s. 5d. per acre was based upon the supposition that every drop of water in the tank was spread upon the land. —J. T. S.

† It was not hereby intended that the water must traverse these 300 or 400 miles; the distance run would of course vary with the situation, from a few chains possibly, to a number of miles.—J. T. S.

15 per cent. ; and if 3 per cent. were allowed for repairs, superintendence, and management, it left 12 per cent. to be divided between the proprietors of the old and new works; and he believed this to be a fair estimate. He had no wish to exaggerate; but he thought it was right to sift an important question like this, and if he had made any mistake, the Chief Engineer of the Company would no doubt correct him.

There was one more point he must advert to—a point of expenditure, viz., Who was to insure these large works against accident after completion? He thought Government would, on general principles, be disinclined to grant concessions for reservoirs, if they believed the parties were likely to realize 46 per cent. from them. They might still more hesitate to give a concession unless they had security that, in case of failure, there would be some funds to meet the loss. To give an idea of the magnitude of these works, he might state that the proposed reservoirs were four hundred times the size of the Bradford reservoir, near Sheffield, the failure of which caused so much disaster and loss of life and property some years ago. It was true the country was not densely populated, but there were towns and villages, and a good many inhabitants, within reach of danger. Therefore it might be supposed the Government would require security, in connection with works of the magnitude referred to, and the provision of some party responsible for, and able to make good, any damage.

Mr. Russel Aitken said, the quantity of water required to irrigate a certain area depended very much upon the nature of the soil, as well as the crops to be raised. In the case of sandy soils a large quantity was wasted, as the water soaked into the ground, thereby raising the spring-level of the country. The value of water depended very much upon the nature of the rainfall. In the Concan in Bombay and other places, where the monsoon rainfall was most abundant, a supply for one crop could always be depended upon, but this was not the case in other parts of India. Then, as regarded the crops raised, in some parts the produce could not be disposed of without great cost for land carriage. The distance from a market made an enormous difference in the value of water for irrigation purposes. Those who embarked in irrigation projects were apt to consider that, as soon as the water was provided, it would be taken up immediately; but that was often not the case. In the first place, there must be population to cultivate the ground; then the cultivators must acquire capital to buy bullocks, build houses, and obtain agricultural implements. Therefore the expectation of an immediate return from these works was, he thought, a great mistake. The returns from the Ganges canal varied from 1 per cent. up to 2½ per cent., after paying working cost, which, even in a fully developed canal, amounted to 25 per cent. of the total revenue, and it was only in 1868-9 that it paid 7¼ per cent., and that was an exceptional year. In the case of the large returns reported of some of the Government works, they had been constructed under very favorable circumstances, so far as regarded the natural facilities afforded by the ground, and also by the comparatively low rates of labor which then prevailed.

Large canals in the deltas of Madras had been constructed for about Rs. 7,000 per mile, and that was a very cheap rate when compared with some new canals there, the construction of which had cost at least Rs. 70,000 per mile. Thus, returns which now paid 30, 40, or 50 per cent. on the smaller cost, would give but 3, 4, or 5 per cent. on the larger expenditure; so that the first cost of the works produced a material effect upon the returns of profits.

The actual value of water in any canal varied so much that no definite conclusions could be given. On the Ganges and the Eastern Jumna canals, the annual revenue for a discharge of one cubic foot of water per second was as under:

	Ganges Canal. Rupees.		Eastern Jumna Canal. Rupees.
1866-67....	374	....	522
1867-68....................	390	....	519
1868-69....................	525	....	653

The water-rate was only about Rs. 2 per acre per crop; whereas in Madras and Bombay it was much higher.

In Bombay he had made a number of observations fruitlessly to find the quantity of water required to cultivate land. Waste, as in waterworks in England, was the chief difficulty. As to the different values of water, he might give one instance to show how it varied. In calculating the value of water from a proposed reservoir about 50 miles from the town of Bombay, he came to the conclusion that a cubic foot per second, for eight months of the year, was worth Rs. 715 per annum for field cultivation, while in the Island of Bombay water was worth, for market gardens, Rs. 8,200 per cubic foot per second, or nearly twelve times as much. It depended upon the crops cultivated, the nearness of the market, and whether there was population to take up the water supplied.

Although irrigation works in India did not, as a general rule, offer a field for profitable speculative investment, yet there could be no doubt as to the duty of the Government of India in this matter. Not only did the Government get large revenues from the water-rates, but canals contributed to the revenue in many indirect ways. In 1868-9 there would have been a famine in North-western India but for the Ganges canal and other canals. The Government, being the proprietors of the land, derived revenues from the land-tax, as well as the water-rates; and if there had been no crops to gather, the Government would have lost the land-tax, whereas they had the benefit of both land-tax and water-rates. In many places, where it would not pay a private company to construct works for irrigation purposes, it paid the Government to do so. In Poonah, a large garrison town, the Government were constructing irrigation works; but he doubted whether they would give any considerable return upon the outlay, though, when the effects of irrigation in reducing the price of forage, and other benefits resulting from a supply of water, were considered, there was no doubt whatever of the necessity for those works being undertaken.

One other point he would mention, viz., the difficulty there was in following this discussion owing to the varying quantities that were spoken of. In Madras the calculations were at per cubic yard per hour; in the north-west the rates were taken at per cubic foot per second; while in Bombay he had been in the habit of calculating in million gallons. It was very desirable that the measurement of water in irrigation works should be reduced uniformly to the cubic metre per minute, which would be better than when several varying standards were employed.

Mr. J. Aird observed that from the drawings there appeared to be a total absence of any puddle gutter—a work which was accustomed to be regarded as an important element in the construction of large reservoir banks. Experience showed that when a leak occurred in a reservoir bank, it was difficult to stop it in the absence of a puddle gutter, or some protecting material of that sort. He would be glad to hear what means had been taken to protect the slopes of these reservoirs. If they were of the enormous area described, with the varying climate, heavy rains, and strong winds, they must be exposed at times to much wash, and without adequate protection upon the slopes there might be considerable danger.

Mr. A. Jacob stated that there was a large waste of water in the beds of the rivers. He had gauged many rivers in India, and found that the amount of water discharged at the head was nearly the same as at the outfall. The tributary streams discharging into the main channel were numerous, and it was evident that much of the water must be lost by evaporation. There was an old saying in India, that irrigation works on rivers increased the discharge of the river; or, in other words, that there was more water got out of the river than it appeared to discharge above the works. Keeping this in view, it was surprising to see the important results produced by placing dams across rivers at intervals of 5 or 6 miles asunder.

He dissented, to some extent, from the views expressed by the author as to the superiority of high embankments. No doubt a reservoir of great depth gave a less degree of evaporation, *cæteris paribus*, than a shallow one. But shallow tanks were easier of construction by native labor, and for a given quantity of earthwork the tanks were cheaper, because the material was at hand; and when the work was performed by basket labor, everything, as regarded cost, depended on the distance from which suitable material had to be carried, which in large banks was sometimes very great. At the present time the Government fixed 12s. as the basis on which the financial return was to be calculated. Seven or eight years ago, a uniform rate of Rs. 1 per acre was fixed by Government; and though he had matured many projects, none of them could be calculated to pay on such a low basis. It seemed very small, when it was notorious that the natives were prepared to take water at Rs. 15 to 20 per acre irrigated. Unless the Government would charge at a fairly remunerative rate, as the natives would do themselves, neither Government nor private companies could expect to get a reasonable return for their money.

Mr. Hemans, Vice-President, remarked that 5,000 cubic yards turned into cubic metres or tons, represented 3,750 tons, equal to a depth of 37½ in. of water per acre. That, at the rate of 12s. per acre, would be at the extremely low price of $\frac{3}{100}$ of 1d. per ton. He did not understand how a crop of rice could absorb such a large amount of water as 3,750 tons per acre. Colonel Smith said it should be 6,000 cubic yards. It was customary in England to irrigate with diluted sewage at the rate of 5,000 tons per acre; but from that land 60 or 70 tons per acre per annum of the rankest and richest grass crops were taken, in a series of crops of 5 or 6 tons each. He wanted to know how that quantity of water could be absorbed or necessary, in addition to the natural rainfall, and whether the quantity stated was applied to one crop or two crops of rice per annum; and further, how it was possible the profits stated could result from the price of $\frac{3}{100}$ of 1d. per ton of water.

Mr. H. Conybeare had given some attention to the impounding of water, having constructed for the water supply of Bombay a reservoir covering 1,400 acres, and in parts upwards of 80 ft. in depth, which he believed was one of the largest modern works of this description. No one could have witnessed the almost magical results of irrigation in tropical and semi-tropical climates, in converting a desert into a garden, without feeling a strong desire to be able to make out a good case in favor of the extension of irrigation as a commercial undertaking. It was therefore with great regret that he had come to the conclusion, that no such case had as yet been made out, at least as regarded tank irrigation. Obviously the most important element in the calculation was the cost at which the water could be stored; but, unfortunately, there was still great uncertainty, and widely differing opinions, as to the number of cubic yards of water that could, under average circumstances, be impounded for a rupee. The author of the paper had assumed the quantity to be 700 cubic yards in favorable cases, and 340 cubic yards in unfavorable cases. The cost of the earthwork in the dam was taken at only 3d. per cubic yard, but it was doubtful whether such work could be executed under 6d. per yard. Moreover, these calculations appeared to be entirely based on estimates; whereas on a point of this practical nature, and of such great importance, it was only safe to rely on the basis of accomplished facts. To be satisfied on such a matter there should be official records showing the actual particulars of cost, and also the contoured plans of a number of reservoirs actually executed, by which the storage capacity of each might be computed, together with such detailed drawings of the dams, etc., as would allow of the quantities of the work involved in impounding the water being accurately checked; such data, in fact, as had been afforded, in respect to the irrigating tanks in Ajmeer and Mairwara, by Colonel Dixon's work. A book had been published by Sir A. Cotton, in which reference was made to the enormous returns that works of irrigation were calculated to yield in India as commercial investments, and in which this work of Colonel Dixon's was grievously misquoted. Sir A. Cotton stated (page 123) that under ordinary circumstances storage reservoirs could be constructed at as low a rate as R. 1 (2 shillings) for each 2,000 cubic yards of water stored, and under favorable circumstances, to store thrice the amount; and he stated (page 254) that in the one-hundred and twelve irrigating reservoirs constructed by Colonel Dixon in Ajmeer, in Rajpootana, the average cost of water was one rupee for each 8,000 cubic yards of water stored.

Colonel Dixon's work for impounding water in Rajpootana, of which Sir A. Cotton spoke so highly, afforded the most economical examples as yet on record of works of this description. The Government of India were of opinion that "it would have been impossible, in almost any part of India, or under any other superintendence than Major Dixon's, to have constructed such works." Accordingly the Court of Directors requested that Colonel Dixon would prepare a report of what he had effected in Mairwara, and a detailed account of the improvements recently made in Ajmeer, accompanied by scientific plans, sections, and drawings, of his more important works, founded on actual survey and measurement. They further ordered that, when prepared, such report and illustrations should be printed and circulated at the expense of the Government of India, for the guidance of officers engaged in similar operations. The report so called for was subsequently published in a quarto volume, containing scientific descriptions and illustrations of eight of Colonel Dixon's principal storage reservoirs, together with a general description of the remainder.

A comparison between the rates at which Sir A. Cotton so positively calculated on impounding water, and at which he stated that Colonel Dixon had impounded water, with those actually obtained in the most economical works of Colonel Dixon's extensive practice in Rajpootana, would afford no unfair criterion for testing the general accuracy of Sir A. Cotton's figures and calculations. It would appear, on instituting such comparison, that Sir A. Cotton had calculated the cost of storing water about ten times too low; and that the final cipher ought in most cases to be abated from his numerical statements. For it was to be presumed that the eight examples of reservoirs which Colonel Dixon had selected for detailed illustration, out of a total of one hundred and twelve, would be considerably more than average specimens; as it was, indeed, known they were, from the particulars afforded by his tables regarding his less important and unillustrated works. Yet, on analyzing the elements of the eight model works so selected, it appeared the most economical result obtained was 688 cubic yards of water per Rupee, the lowest only 102 cubic yards per Rupee, and that the average number of cubic yards of water stored for each Rupee, expended merely in labor and materials, was only 284 cubic yards per Rupee, and for four of the eight model examples, was under 200 cubic yards per Rupee. Whereas Sir A. Cotton stated (p. 123): "I calculate that water can be stored at 2,000 cubic yards per Rupee (2 shillings), an estimate which is the result of long experience among the tanks of the Carnatic. Without any remarkable advantage in the site, a bund may be made almost anywhere at this rate; but in many situations where the form of the ground favors it, thrice this amount may be stored for a Rupee (2 shillings)." He also estimated the average results of Colonel Dixon's practice in Ajmeer at 8,000 cubic yards per Rupee. Moreover Colonel Dixon's tanks were constructed at exceptionally low rates. The masonry in mortar was only 1s. 6d. per cubic yard, and the earthwork, "well beaten and rammed," was executed at the low rate of $1\frac{5}{8}$d. per cubic yard. Now, Engineers of Indian experience would know that earthworks of that sort could not be sublet in India at the present time at less than four times the rate that Colonel Dixon paid for his work. Sir A. Cotton remarked in his book, that if these reservoirs had been larger (the eight selected for illustration in this work were much larger than the average of such works in India), the water could have been more economically stored. That was true theoretically; but, on the other hand, the sites where enormously large quantities of water could be economically stored were very exceptional, and where they did occur they usually involved exceptional sources of expense, which detracted materially from their theoretical economy. In the case of the large reservoir which he had made at Bombay, covering 1,400 acres, and 80 ft. deep, with every attention to economy, he was only able to store 162 cubic yards per Rupee, and that work was done by contract. Therefore he was afraid no case had been made out for the extension of tank irrigation, as a commercial speculation, in India. The results were so uncertain; there were so many circumstances to cause variation in the profits; and, as he had shown, the actual cost of impounding water was so much greater than it was usually stated to be. But there were a very large number of ancient tanks throughout India and Ceylon, that had become breached for want of a waste weir, the repair of which could not fail to prove remunerative as a commercial investment. Even in cases where irrigation would not answer as a commercial investment to outsiders, it would still be worth the while of the Government to undertake such works; because in most parts of India Government stood in the position of being the universal landlord, and the amount of indirect profit they would get in saving the remissions of land-tax in seasons of drought would make to them the difference between a loss and a profit. Moreover, were a large proportion to the land in any district under irrigation, famine and its incidental calamities and losses would be rendered impossible. There was, therefore, no question regarding the enormous importance to the Government of the extension of irrigation.

He was not acquainted with any dam in India, constructed by natives, which had a puddle wall; but the bank was usually an enormous mass of earthwork, and being built up with basket labor, and being thus deposited in very thin layers, by means of the constant trampling of the men, women, and children, employed in carrying the baskets, the whole structure was rendered almost as compact and impervious as puddle. Some of the great reservoir dams in Central India, like that of the Saugur lake, consisted of two parallel walls enormously massive, and built at so considerable a distance apart, that in the interval (filled in with well-packed earth) there were often forest trees and hamlets; thus the fort, and a portion of the city of Saugur were built on the dam of the Saugur lake. He knew of no native reservoir with a bye-wash, and even a waste weir was often absent.

Mr. F. C. Danvers said he had endeavored to ascertain, from published reports, the commercial value of water in India, and had been struck with the variation of returns from canal and other irrigation works. He found, from the reports annually issued by the Government, that the sum of £5,712,000 had been spent upon irrigation works in Madras, the Punjab, and the North-western Provinces, the returns upon which were as follows: Madras, 29.41 per cent.; Punjab, 7.01 per cent.; and the North-west Provinces, 5.06 per cent.; yielding an average return, on the whole, of 10.5 per cent.

In Madras, of the 32 principal irrigation works, eighteen showed a balance of income over expenditure, and fourteen yielded no direct net return, but showed a deficit. Of the remunerative works he might mention the following:

	Cost.	Net Revenue.	Return.
	£.	£.	Per cent.
Lower Coleroon....	11,647	39,442	Over 338
Upper Coleroon....	23,986	42,561	177
Vallaur Anicut	8,215	10,442	127
Godavery Anicut..	432.886	175,116	40.4
Pennair	59,050	6,470	Nearly 11
Kristna Anicut....	271,720	20,747	7.6

In the Punjab the direct income gave 7.01 per cent.; but if the indirect income was added, the return was equal to 12.52 per cent. upon the capital outlay for irrigation works. The indirect revenue, in the shape of enhanced land tax, arising from the beneficial effects of irrigation upon the land, was calculated at 12 annas, or 1s. 6d. per acre. Of the six large irrigation works in the Punjab, only two returned a profit from direct revenue, viz., the Western Jumna and the Baree Doab; but, including indirect profits, all but the Upper Sutlej were profitable. The Western Jumna canal showed a direct net profit of 35.82 per cent.; and the Baree Doab of only 2.86 per cent. The former was one of the oldest of the Mogul canals, and irrigated 496,543 acres; the latter, a work of modern times, irrigated 233,927 acres.

It had been stated that, in the North-west Provinces, the net returns were 5.06 per cent. on the entire capital expended; but a portion of the expenditure was upon works not yet opened. With that deduction the return was equal to 5.13 per cent., and it was estimated that if a fair addition was made for increase of land revenue, the returns would be equal to upwards of 8 per cent. Of the seven large canal systems in the North-west Provinces only three returned a net profit, viz., the Ganges, the Eastern Jumna, and the Dhoon canals. The other four worked at a loss, so far as direct revenue returns were concerned. The Ganges canal showed great fluctuations in the returns obtained respectively in seasons of drought and good monsoon rain. In the year 1868–9 the net profit was 7 per cent., and in the following year only 4 per cent., which was mainly owing to the difference of rainfall. The Eastern Jumna canal returned a profit of 23.33 per cent., and the Dhoon of only 2.58 per cent.

With reference to the value of water, Colonel Dickens, in his Report on the Soane canal, laid it down that, "Excepting in the rich land near the Ganges and a few other favored spots, the unirrigated crops of wheat and barley are very scanty, and are said to produce only 256 to 640 lbs. per acre; and those irrigated once or twice yield only from 512 to 1,024 lbs. per acre; irrigated three times, the crop is said to yield from 896 to 1,280 lbs. per acre; but the people told me if they could irrigate four times, using abundance of water, they would get from 1,280 to 1,920 lbs. per acre." To irrigate thoroughly, Colonel Dickens considered 17,600 cubic feet of water per acre were necessary for the season. The average assumed in drawing out the projects for the Baree Doab and the Ganges canals, derived from data afforded by the Jumna canals, was that each cubic foot of discharge per second was capable of actually irrigating 218 acres. In the Soane canal project, Colonel Dickens estimated the effective duty of water at a somewhat higher rate.

The actual results obtained from some of the principal canals in Northern India were as follows: Area irrigated per cubic foot per second of water actually employed in irrigation, after deducting volumes escaping at terminals—

	Ganges.	E. Jumna.	W. Jumna.	Baree Doab.
Acres	186.03	268	240	154.91

He was unable to obtain definite information as to the extent irrigated by a cubic foot of water per second per acre in the Madras Presidency; but he had seen a calculation in which the rate laid down was 2 cubic yards per hour per acre, which was equivalent to 200 acres for each cubic foot of water per second, and that agreed nearly with the estimate for the canals of the North-west Provinces. In older works, as had already been shown, the value obtained was higher, viz., 240 to 268 acres; while the Ganges and the Baree Doab yielded the less return of 186 and 154 acres respectively.

The water-rates realized per cubic foot of discharge per second were—Ganges, Rs. 378; Eastern Jumna, Rs. 538; Western Jumna, Rs. 499; Baree Doab, Rs. 127.9; and the water-rate per acre irrigated was nearly the same in each case, viz., Ganges, Rs. 2.25; Eastern Jumna, Rs. 2.32; Western Jumna, Rs. 2.41; and Baree Doab, Rs. 2.35. This was for the autumn and spring crops. The rate varied slightly according to the crop; thus, on the Ganges canal, for the autumn crop it was Rs. 2.57 per acre; and for the spring crop, Rs. 2.00 per acre; the mean being Rs. 2.25.

In conclusion, he would draw attention to recent numbers of "Professional Papers on Indian Engineering," in which the semi-official correspondence addressed to the private secretary to the Viceroy, by Major Corbett, B. S. C., on the question of, "Is Irrigation necessary in Upper India?" was published by desire of the Viceroy. It was contended that superior cultivation to what now exists was alone necessary; that at present the ground was only scratched a few inches deep with the native plough; and below that there was a hard crust which prevented the water filtering through; and that if that was broken up, and the cultivation carried deeper, there would not be the same necessity for irrigation, because evaporation from the land would not take place to so great an extent.

Major J. Browne, R. E., stated that in Upper India tanks were not generally employed, as the slope of the ground was so great that it would require dams of great height to hold in even a moderate supply of water. In some parts, the foot of the hills afforded an opportunity for building tanks; but they were on a small scale, and generally ended by drying up and being taken up for cultivation. Mr. Gordon had mentioned that the proper method of defending the masonry in falls, against the violence of the water going over them, was to provide water cushions. No doubt these were beneficial; but another method was employed in the canals of Upper India, which he believed was more efficient; and that was to place on the crest of the dams stout timber gratings, composed of baulks about 6 in. by 6 in., and about 2 or 3 in. apart, and slightly slanting upwards. The effect of this grating was to cause the water going over the crest of the weir to fall in thin films, and consequently with less destructive effect; the velocity of the water was also thereby materially checked. Besides, in Upper India destruction was caused by the drift logs that floated down the canals in floods; and these great logs, 20 or 30 ft. long, taking headers over the falls, smashed everything before them; but the grating protected the masonry from this cause of demolition. These gratings had been used for many years by Colonel Dyas, and they answered as a most efficient protection to the masonry of the falls.

Mr. Latham had mentioned, with regard to the discharge to be provided for in catchment basins, that the formula was represented by—The discharge, equal to a constant quantity, multiplied by the drainage area, raised to the power of two-thirds. That was Colonel Dickens' formula, with one slight difference, viz., that the drainage area was raised to the power of three-fourths instead of two-thirds. This did not make much difference in a small drainage area, but it did in large catchment basins.

At the foot of the Himalayas the rainfall was very great, and exceeded anything that had been mentioned; coming up to 4, $4\frac{1}{2}$, and 5 in. per hour. In such districts the formula which gave the best result, taking the discharge in cubic feet per second, and the drainage area in square miles, was—Discharge equal to 1,200, multiplied by the drainage area raised to the power of $\frac{3}{4}$. He believed the circumstances in Madras were somewhat different; but in Upper India, and particularly in the Punjab, it appeared to him that canal irrigation was largely supplied to districts where it was not so much required, and denied to districts where it was most required. The rainfall in the Punjab varied inversely as the distance from the great Himalayan chain which ran to the north, and on which the rainfall varied from 80 to 210 in. In the Sub-Himalayas it varied from 40 to 60 in.; at 120 miles from the hills it was not more than 30 or 40 in.; going to 250 or 300 miles from the hills, the rainfall came down as low as 3 or 4 in.; while in Scinde it was scarcely more than 2 or 3 in.

The depth at which water was found in wells followed the same rule, varying as the distance from the mountains. Where the rainfall was not under 30 in., and the depth of the wells did not exceed 30 ft., canal irrigation, though advisable, was not absolutely necessary. The great difficulty was to get sufficient water to irrigate those districts where canal irrigation was alone possible. Most of the water that came down the Baree Doab canal, and a great portion of that which came down the Ganges canal, was taken up by those districts where the wells were not more than 30 ft. deep; and the result was that the villagers had allowed their wells to choke up, and had become entirely dependent upon the canals.

The moral of this was, that in the great projects that had now to be taken in hand, well irrigation should not be entirely lost sight of. There was no water to spare; and it seemed to him economy had not been observed, where canals were employed in districts where irrigation could be practised, even to a small extent, by wells. No doubt canals must sometimes be taken through districts where well-irrigation was possible; but the canal ought to go through such districts not as an irrigation canal, but merely as a channel conveying water down to the lower districts, where the rainfall was so small that irrigation was absolutely necessary. He was aware that there was a great deal to be said against well-irrigation, and that it cost so many pounds, shillings, and pence, to hoist so many cubic feet of water from a given depth. As a purely mechanical arrangement, he did not put well-irrigation in competition with canal-irrigation; but in a commercial and social point of view there was a great deal to be said in favor of well-irrigation. Except perhaps the Civil Courts, there was no greater cause of discontent in India than canal-irrigation. Villagers who used their own wells were not exposed to be bullied by canal understrappers, who might threaten to cut off the water, and compel their attendance in Civil Courts; and they were free from official restrictions in the distribution of the water. Then, again, as a commercial speculation, canal companies must necessarily lay out a great sum, which could not return any interest at first starting, and probably for a very long time; whereas money laid out in wells, if it paid at all, would pay very quickly; as a well could be started, and be in full operation, if not more than 30 ft. deep, within a month after it was begun. A company for well-irrigation could feel its way without risk; whereas a canal company must lay out money freely, and, getting no return for a long time, might find itself, perhaps after twenty years, in the receipt of 1 per cent. dividend per annum. As to hoisting water from the well, in many parts of India, particularly below the hills, the wind was for the most part very steady during the morning and evening, and a good deal could be done by windmills. Then, again, by irrigating by wells the waste was avoided which always resulted more or less from canal-irrigation, and spoilt the crops by souring and oversoaking the soil. He had always understood from such cultivators as he had spoken to, that crops raised from well water were of a better quality than those raised from canal water. He could not say whether it was due to the higher temperature of the well water, or to any chemical difference in the water itself, but canal-raised were, he believed, generally inferior to well-raised crops.

He did not wish it to be supposed that he at all undervalued the vast benefits of canals. They were indispensable, no doubt, where irrigation could not be obtained by other means; but in the ambitious projects of the Government and of private companies, he thought they had too much lost sight of the question of well-irrigation; and it had apparently been forgotten that there was possibly as much water below as above the surface. It was admitted, that in Upper India, there was barely enough water on the surface to irrigate those districts where well-irrigation could not be employed. Therefore, for every acre of land irrigated by canals which might have been irrigated by wells, an equal acreage in another part of the province was condemned to perpetual barrenness; and this would be the case whenever canal water was supplied to districts where well-irrigation was possible.

In a social and commercial point of view irrigation by wells had many advantages, although as a mechanical arrangement he did not wish to defend it. It seemed to him that, with the improved means of communication in India, well-irrigation was a means of preventing, to a great extent, and at a very early period, the recurrence of those famines which might come at any moment, and which might occur for years before those more ambitious projects, which he did not, however, undervalue, had been well started, and had begun to do any good to the country.

Mr. G. Gordon, in reply upon the discussion, said Mr. Latham had inquired what allowance had been made for the discharge of storm-water from the reservoirs, and as to the calculation of it in reference to maximum rainfalls in India. He had used no formulæ. He had ascertained what the maximum flood discharge of the rivers had been during a period of 15 or 20 years, and that was exceeded by a recorded flood by perhaps nearly twice as much. It could not be accurately measured, because there were no reliable marks to go by; and that extraordinary flood was calculated as the measure of the maximum discharge. He did not think any general formula could be used for all places; a formula founded on observed rainfalls and floods in one district would be useful for other districts similarly circumstanced, where the rivers had not been gauged; but in no case could observations with regard to climatic conditions be dispensed with. He agreed with Mr. Latham, that the question of the quantity of water per acre necessary for efficient irrigation was a difficult one, and had never been, and probably could not be, definitively settled; because different soils, as well as different crops, required a greater or less supply of water, according to the peculiar circumstances of the case. Rice required more water than any other crop. The result of the experiments made by the Madras Government was to fix the quantity at 2 cubic yards per hour per acre, or 66$\frac{2}{3}$ acres per cubic foot per second. That corresponded to 5,000 cubic yards per acre per crop, and was calculated to be the quantity required for rice; while more valuable crops, which would bear a higher water rate than rice, took less water to irrigate them. Colonel Smith objected to the quantity of 5,000 cubic yards per acre, and thought that at least 6,000 cubic yards should be allowed; but a few years ago Colonel Smith, in reporting on a project of his, had assumed 3,600 cubic yards as the quantity required for the second crop, which was the one a reservoir had to supply. He mentioned this to show the quantity had not been agreed upon or calculated with certainty for different districts; but in estimating, it was necessary to take some standard; and that of the Madras Government, of two cubic yards per hour per acre, was what he had adopted.

Speaking of the cost of the water, Colonel Smith was mistaken in saying he had taken an imaginary average reservoir. It was a reservoir carefully surveyed and estimated, and was, out of several so estimated, the one least favorably constructed for the storage of water. It was not the favorable one proposed to be constructed by the Madras Irrigation Company—favorable with reference to the number of cubic yards of water per rupee stored. The case of the proposed restoration of the Mudduk tank was an extremely favorable one, and he had never met with any other instance where so much water was stored at so small an expense. But Colonel Smith objected to that estimate, because, he said, the supply was uncertain, and he compared it with the Maury Convai tank, of which the supply had been proved to be uncertain. Colonel Smith seemed to think these tanks were in the same neighborhood, whereas they were nearly 100 miles apart, and the characters of the two districts were totally different. The one was on the inside slope of the Western Ghats, and the other on the table-land of Mysore, where the rainfall was very precarious. They were no more comparable than were the Rivington Pike District and the east coast of England. The capacity of the tank was not quite equal to the maximum discharge of the river. No doubt, in that instance, it would be better if the tank were capable of containing rather more than the average discharge; but that could be effected, not at double the cost, as Colonel Smith supposed, but by the usual expedient of putting in planking on the waste weir to a height of 5 feet. The rivers rising in the Ghats fluctuated much less than those in the table-land. The usual way was to put planks between posts on the waste weir, and to take them down in case of heavy floods.

The evaporation had been calculated from observations taken in the neighborhood, the monthly evaporation being multiplied into the mean area exposed every month. The tank was just filled at the end of the monsoon season, and the small surplus of water now discharged by the weir after that was not taken into the calculation, although it was sufficient to make up for a great part of the loss by evaporation. The tank was full only at the end of the season; then the water was gradually drawn off, and the tank was supposed to be emptied in four months. For each of these months he had estimated the quantity carried off by evaporation over the exposed area of the tank, and the total amounted to 5 per cent., instead of $6\frac{3}{4}$ per cent., as Colonel Smith calculated by a rougher method.* Multiplying that by the four months, Colonel Smith calculated the total evaporation to be 20 per cent. of the contents of the tank. That would bring up the evaporation to 120 inches per annum, an amount never yet registered to his knowledge. Colonel Smith had mentioned a tank in which $\frac{5}{8}$ths of the water was wasted by evaporation, and only $\frac{3}{8}$ths was put upon the land; but that tank was a very shallow one. If the tank had a depth of water of only 60 or 70 in., with an evaporation of 30 in., more than half would pass away by evaporation; but the case was very different in a tank 60 or 70 ft. deep. Even in the dry season there was always a small stream running into the tank, which was filled by the monsoon supply alone. The loss from the canal which Colonel Smith referred to was not much, and the water quickly deposited a layer of fine mud on the bottom and sides, as happened in filtering beds. A case was known where a channel in sandy ground had to be widened, and it had been so well lined with natural puddle, that the enlargement was carried on without stopping the supply; the excavation close to the old channel was quite dry even below the level of its bed. The evaporation of the water of the canal was not ascertained, because it was included in the 2 cubic yards per hour per acre; in which, too, the evaporation in the passage of the water from the reservoir down the river to the canal was also included. The bed of the river was rocky, with here and there layers of sand left by the floods; lower down, about Kurnool, there was more sand. Even after the streams ceased running, the drainage of the country into the river, which was the main drain of a very large district, was more than sufficient to make up for the loss by evaporation. It had been gauged in the hot weather, and the discharge was found to be less in the upper than in the lower part; in 1868 it was only one-eighth. This differed from Mr. Jacob's experience in the Bombay Presidency, where he found that though a good deal of water flowed in, the evaporation made up for it, and the river discharge at the lower end was more than it was at the upper end. The objection that the reservoir did not hold the whole supply did not apply to the other reservoirs estimated for, which were more favorably situated; because there the difficulty was not how to fill the reservoirs, but how to get rid of the surplus water. The largest reservoirs he found took little more than half the monsoon supply of the river; and then the water required to be embanked to prevent it running over a water-shed into another river. The difficulty was to get sites where the floods could be impounded. The Mudduk Masoor tank was capable of impounding the whole flood water. He could not accept Colonel Smith's conclusions, that only half the water stored was used on the fields. Colonel Smith gave no figures in support of that conclusion; and he believed 15 per cent. would be the full amount of waste, assuming the Government rate of supply of 2 cubic yards of water per hour per acre in the main canal.

Mr. Aitken had stated that canals which cost only Rs. 7,000 per mile, gave returns of from 40 to 60 per cent., and that, therefore, others costing Rs. 70,000 would yield only 4 to 6 per cent.; but the quantity of water carried must be reckoned, not the cost per mile. He admitted that the different measures used, viz., the cubic yard per hour in Madras, and the cubic foot per second in Bengal, and in some cases gallons, were very inconvenient; but the difficulty would not be remedied by the introduction of a fourth measure, the cubic metre. He thought the reckoning by cubic feet per second was the most handy.

From time immemorial it had been the

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* The months March and April, when the evaporation was greatest, were those when the area of water in the tank was least.

custom to dispense with puddle in native works, and in the parts of India he was best acquainted with, there was no clay to make puddle with; in fact, there was a district 250 miles long and 100 miles broad where no stiff clay was to be found. There was at first a little leakage in a new bank, but it soon got puddled by the deposit from the muddy water, the banks became impervious, and this was effected by the silt existing in the river. In some cases the slope of the reservoir banks was protected by large stones built in the form of steps, and in others they were laid on the flatter slopes. Breaches often occurred in small tanks; they were generally repaired by forming a ring dam in front, and sometimes the bank was cut to relieve the pressure of the water. That was done, when it was possible to do it, where the bank was on rocky ground, so as to cause as little damage as possible.

A great part of the water was evaporated after it was turned on the fields. The evaporation in places exposed to the hot winds was $\frac{1}{3}$ in. per day, and a crop of rice was under water about a hundred days; so that about 33 in. would pass away by evaporation, which left only 5 or 6 in. to be disposed of by infiltration and drainage. The evaporation was perhaps reduced in the last months of the crop, by the water being sheltered by the grain, and, he believed, might amount to 30 in. altogether.

In experiments made by Colonel Meadows Taylor on the wells of the Deccan, it was found that 6,000 cubic yards was the quantity per acre used for the two crops of the year. The first crop consisted of turmeric, chillies, ginger, plantains, and other valuable garden produce; the second crop was wheat or cereals. For those two crops rather less than 6,000 cubic yards of water per acre were sufficient, and in the use of wells there was very little water wasted, as the water was raised at a cost to the ryots of Rs. 27½ per acre, exclusive of interest upon the cost of the wells

The reservoir mentioned by Mr. Conybeare was a comparatively small one, and he agreed that a small quantity of water could not be stored economically in India for the purposes of rice irrigation.

As to the revenue to be derived from irrigation works, if the Government fixed the rate so low that it was not remunerative, it was likely to give them a bad name. It was said they were not constructed because they were not remunerative; but they were not so only because the Government would not allow a charge which the people were ready to pay.

He thought the plan adopted by Colonel Dyas for breaking the force of the water in the falls of the Baree Doab canals an admirable one. The effect of the gratings was to break up the falling water and distribute it over a larger area, but he thought the plan was less applicable to weirs in rivers, to which the remarks about water cushions in the Paper referred, as all the length that could be got for clear overfall was needed, and the introduction of gratings would require a greater length, or else the level of the water must be inconveniently raised. He thought them excellent for canal falls, and they seemed to have answered their purpose perfectly. The well-irrigation, which seemed to please the people in the part of India described by Major Browne, would never be extensively practised in the South. In the Deccan 4½, and in Bellary 3 acres, were the most one well would irrigate; the water was slightly brackish generally, and the cost of raising it by the cheapest method, if animal power was employed, was too high—55s. per acre in the Deccan, probably 80s. in Bellary, and 60s. at the experimental farm at Sydapett, Madras.

Mr. A. A. West supplied, through the Secretary, a table of the evaporation at Bombay, during the dry season, from a surface of 100 sq. in. of water in a cistern, open to the air, but shaded from sunshine:

	Days.	Inches.	Inch. Average.
1814, October......	31	4.80	.155 a day.
“ November....	30	4.60	.153 “
“ December....	31	4 45	.143 “
1815, January.....	31	4 15	.134 “
“ February.....	28	3 85	.137 ‘
“ March.......	31	4 65	.155 “
“ April........	30	5 55	.185 “
“ May.........	31	5 30	.174 “
Total....	243	37 35	.154 “

The rains of 1814 ended on the 14th of October. Those of 1815 began on the 5th of June. The greatest evaporation in a day was 0.20 in. in the middle of April and latter part of May. The least was 0.12 in. in December and early in January.

During the month of May the thermometer varied from 90 deg. to 102 deg. Fahr. in the open air shaded from the sun; and from 87 deg. to 90 deg. in the house from 8 A. M. to 11 P. M.

The evaporation at Bombay during the rainy season, under the same conditions as the preceding, was: (See Table A.)

The rains of 1815 began on the 5th of June, and ended on the 16th of October. The evaporation in August was high; it was 2.35 in. in 1814, and 2.45 in. in 1816. The greatest evaporation in a day was 0.18 in. in clear weather in July and August, and 0.19 in. in October. On wet days it was 0.10 in. The least was 0.05 in. during continual rains in June and July.

TABLE A.

	Days.	Inches.	Inch Average.
1815, June	30	3 05	.102 a day.
" July..........	31	3 10	.100 "
" August	31	4.60	.148 "
" September....	30	4.45	.148 "
Total..........	122	15 20	.124 "

THE PRODUCTION OF TRAFFIC AND THE TRANSPORTATION OF FREIGHT AND PASSENGERS.

BY MARTIN CORYELL, C. E.

From "Transactions of American Society of Civil Engineers."

Early history and the ruins of ancient civilization attest that Asia and a part of Africa were first densely populated; that agriculture, commerce, and the arts were developed in high degree, and that the carriage and exchange of products of the soil, materials for building, munitions of war, and the objects of commerce then were necessary to a luxurious people. Among the remains of that age, there is nothing to show the use of modern substitutes for manual labor or beasts of burden, in performing the work of inland transportation.

China and Egypt had canals at an early day, and used their rivers similarly for travel and transportation. Greece and Rome employed ships in commerce and for war, constructed canals, opened roads, and erected bridges, the remains of which are still to be seen.

Coming down to modern times, the first canal in France—between the rivers Loire and Seine, 34½ miles long—was begun in 1605, and completed 37 years afterward; in England, the first—the Bridgewater Canal—was begun in 1758. Coaches were introduced about 1605, prohibited in 1635, and in 1770 only 1,000 were registered in the whole kingdom. With coaches, turnpikes, or roads on which tolls were levied, came into use; about 1790, Telford and McAdam began improving them, and in 1819 Parliament appointed a committee to examine into their condition.

In this country—soon after the Revolutionary war, as agriculture, manufactures and commerce began to thrive, the people, and particularly those on the seaboard, saw the need of a ready means whereby the products of the soil and the forest could be exchanged for commodities brought over the seas or made up in town and city. The experience of older countries was consulted, and turnpikes were determined on, not only as meeting a want much felt, but as a profitable investment for surplus funds; charters therefore were granted by State authority, and soon roads were built, connecting growing cities with fertile agricultural regions or thriving manufacturing centres.

Pennsylvania was the first State to have regularly a graded and stoned turnpike, which was chartered in 1792 and finished in two years; it was from Philadelphia to Lancaster, 62 miles long, and cost $465,000, or $7,500 per mile. So beneficial were its effects upon trade, and the country through which it passed, that it was extended to Pittsburgh, the most westerly town at that period, 303 miles distant, with ascents not exceeding 3¾ degrees, and passengers were carried in post-coaches from there to Philadelphia in 60 hours. When the road was completed, the traffic was not sufficient to pay dividends and for repairs, but in a few years it so increased that double loads were carried in vehicles drawn by 4, 6, or 8 horses, and consequently the tires of the wheels of the "Conestoga wagons" were widened from $1\frac{1}{2}$ to 5 or more inches. The results were that, under the effects of frost, rain, and the heavy traffic, turnpikes became expensive and unprofitable; and people, in good weather, would travel over a parallel road to avoid paying toll. Soon they were unpopular and condemned by the community generally, and most unjustly; for, until over-burdened by the quantity and weight of traffic, they served well their purpose; thereby cities and towns were built up, the lands through which they passed were increased in value five-fold, and the general enhancement of taxable property was ten times the original cost of the turnpikes. Now that they are relieved from heavy and ruinous loads, they are, if well made and kept, as useful and profitable as in their early career.

Canals were next in this country to relieve commerce, by an exchange of productions, and in their construction New York was first, with that ever-enduring monument of enterprise, the Erie Canal, which was the model, and furnished the engineers and contractors for many others throughout the various States. The history of canals is similar to that of turnpikes; the investments made in them were, in a great measure, lost to the original projectors and owners; generally they were located along rivers, subject to injury by extraordinary freshets, and extended so far towards the river's source that the traffic necessarily done in seven months only of the whole year was made unprofitable by the amount of lockage, scarcity of water, and effects of frost.

When the early canals were completed, their capacity for transportation was so far in advance of the needs of the country, that they largely absorbed the traffic of turnpikes without, for years, earning enough to defray expenses and pay dividends; but as it was with turnpikes, wherever canals were located, manufactures, trade and travel greatly increased, cities and towns were built up, and the adjacent country became prosperous and wealthy; consequently, in time the canals were overcrowded with the trade they had reared and were unable to accommodate, and soon, therefore, they too were, in degree, condemned and neglected.

The railroad next claimed public attention for the carriage of freight and passengers, and when the locomotive was made its special adjunct by George Stephenson, it took rank and character which led to a success that completely revolutionized transportation and its various interests. Like the turnpike and canal, the railroad in early years was subject to trials of poverty, want of trade and depression of stock, but now it is triumphant, fearing only that the telegraph may take from it the postal and money business of the country as effectually as it did from its slower predecessors.

At first, railroads were only intended for portages between navigable waters; it was generally conceded that they would for many years be all-sufficient when the rivers and lakes of the great West were reached, and it was deemed useless and impracticable to think of proceeding further without transshipment. The productions of the South and West so accumulated that the labor and delay at points of transshipment became a serious cause of waste and cost, which, added to the cost of transportation, tended to exclude these commodities from Eastern markets.

The scheme of bridging the Ohio, which floats a vast and increasing commerce in fleets of boats of every style, was violently opposed by the Federal Government and the people at large, in Congress and the Courts, to prevent an attempt characterized as chimerical. The history of the Wheeling bridge attests what a grand success it was; it does, and may it ever stand, a pioneer monument of commercial enterprise and engineering skill, proving that traffic by rail need not destroy or greatly obstruct traffic by water. When a few more bridges, as the St. Louis and East River, and a few more tunnels, as the Detroit and Hoosac Mountain, are completed, the chief problems in railroad construction will be solved, and the question "Will it pay?" can be answered.

One of the earliest and boldest innovations of the railroad upon water navigation was when a line was projected and built along the Hudson river. Our worthy and Honorary Member, Mr. John B. Jervis, as engineer, demonstrated that the Hudson River Railroad was not only practicable to construct, but profitable to operate. Most people thought it a wild scheme thus to contend for the trade of a free and noble river like the Hudson, with gorgeous steamboats, moving 16 miles per hour, numbers of sailing vessels and acres of floating timber; all without the least tax for tolls, repairs or management, while transportation by railroad would be subject to the large expenses of construction and operation. The result is before us: now, two double track railroads, well equipped and prosperous, share the traffic with the river—a third is projected, and there is trade enough for all; not to mention the vast consequent improvement of property and increase in values, along these lines, and as far as their connections extend.

Mr. Asa Whitney, formerly of New York, now of Philadelphia, conceived the "audacious project" of constructing a railroad, thousands of miles in length, from ocean to ocean, through a wild and mountainous region, not only for traffic but to build up cities, develop the country, and divert trade from what had been always considered its natural channel, the sea, across an uninhabited continent. Heretofore commerce had directed the means of transportation; now the railroad was to win commerce from nations where before it had scarcely existed. In May, 1849, Mr. Whitney published a pamphlet entitled "A project for a railroad to the Pacific," in which were set forth many of the details of the grand scheme as it was afterwards accomplished. The road has been built for years, and yet his name is rarely mentioned in connection with this, one of the greatest undertakings of modern times. Now the North Pacific and the Southern Pacific Railroads are in course of construction; other lines, through British America and Mexico, are projected; all to compete for the traffic of Asia and the Pacific Islands, and to aid in peopling the large uninhabited areas of this continent.

In contrast to these broad plans for commercial and national progress, attention is called, without comment, to the following extract from a letter of Hon. Jefferson Davis, Secretary of War, dated February 24th, 1857: "Under the appropriation of $30,000, made on the 3d of March, 1855, 75 camels have been imported. The limited trial which has been made, has fully realized my expectations, and has increased my confidence in the success of the experiment."

Cheap, or as they are commonly termed, "narrow gauge" railroads, with light rails and well-constructed machinery, will, in time, be substituted for common roads, as feeders and distributers of main lines. In populous manufacturing or in agricultural districts, where the traffic is insufficient for more expensive lines, these may take it at profitable rates until roads of greater capacity are required.

Although railroads and their machinery, as a means of transportation, seem to be nearly perfected, the studies and services of the engineer are not soon to be dispensed with. A brief consideration of subjects now more or less prominent show rather that the field of his labors will in the future be more extended and diversified; a few of these subjects I will mention.

Marsh and swamp lands are to be reclaimed by embankments, ditching and subsoil drainage; rice, cranberries, cotton and other similar crops are to be irrigated; lands are to be cultivated and their products gathered by the aid of steam machinery; forests are to be preserved from the ravages of fire, and extended over barren lands, to keep up and increase the supply of fuel and timber, and to equalize the amount of rainfall.

The water in our streams is to be stored up in time of plenty, for domestic and sanitary purposes, to extinguish fires, irrigate lands, furnish power, and to maintain the navigation of canals and rivers. Rivers are to be improved and secured; basins, docks, and wharfs for shipping, elevators for grain, and warehouses for merchandise, are to be constructed. Canals are to be reconstructed, an abundance of water for increased traffic provided, and the locks extended to take in without delay, at one time, a steam tug and the boats she may have in tow.

Railroads are to connect the large cities of this continent, located, equipped, and operated to maintain a speed of 100 miles per hour with safety and certainty. Superior and intelligent management must reduce the rates of freight, so that the products of the soil and the mine, in regions widely separated, may be exchanged without loss, and at a fair remuneration to the producer.

Safe and permanent buildings, for commercial purposes, with foundations "strong and deep," are to be erected capable of resisting fire, floods, and the severities of our climate, fitted with machinery for hoisting and moving goods or grain, well ventilated and thoroughly adapted to the secure preservation of the property contained, without danger from loss.

One feature more or less relating to transportation, connected with the mining and marketing of coal, and in a less degree with the handling of ores and the manufacture of iron, has long exercised those managing these interests. The trade demand for coal in special sizes is irregular and spasmodic, whereas its production and preparation by suitable machinery is uniform, day by day, and in such quantities that accumulation of any particular size soon stops the entire work. In early spring there is a large demand for "lump" and "steamboat" coal, and but little for "prepared" or "special" sizes, which hence have for months to be forced upon the market at ruinous prices, or wasted on the "culm" or dirt pile, to make room and keep the "breakers" clear. In the fall and winter this is reversed; orders then come in so fast for "prepared" sizes, that extra machinery is employed to crush the best coal and thus supply the demand at an enormous expense and waste, most of which in the end has to be borne by the consumer.

This loss and more could be saved if proper arrangements were made to transport daily to market direct, the entire production of the mines, and there have storing grounds and the necessary appliances to prepare the material as required for immediate use, so that what is wasted at the mines could be utilized as cheap and useful fuel. More than one-half of the coal in our mines is wasted there or in preparation for market; the mountains of coal dirt which disfigure our coal districts should cause regret and shame to the capitalist, engineer, and miner. All the items that enter into this waste can be taken up and adjusted, so that in the anthracite coal trade alone, 50 cents per ton, or $10,000,000 annually may be saved.

The present equipment of railroads—particularly of those specially devoted to the coal trade—is in design and build adapted to but a limited variety of traffic, and consequently cars are returned empty, or when rolling stock is in great demand, stand for months upon a siding, depreciating in value more rapidly than when used. By the system of car construction, and the want of adaptation to required uses, toll rates are necessarily increased; and, in consequence of this and other abuses, it will only pay to send the choicest and most valuable products to their natural market or place of consumption.

All these things are within the province of the civil engineer; but no one man can singly effect their improvement. It is the aim and end of this Society to include within its membership those who not only can lay foundations under rivers and seas, tunnel beneath lakes and through mountains, span navigable waters, and unite the extremities of a continent, but who, because of their integrity and experience, possess the confidence of those who supply the means, as well as of those who do the work of these undertakings. With such in co-operation, our profession can always perform whatever trade, commerce, or the good of our common country may require of it.

Mr. McAlpine—On the 8th of May, at the invitation of the Chamber of Commerce of New York, I addressed the merchants of the city on the subject of transportation,* a very broad field. Certain results of investigation made in preparing that address may perhaps surprise you, as they did me.

Corn sometimes is burned for fuel in the West, simply for the want of transportation. I compared the cereal production of the United States for the last three or four years with that of the civilized world elsewhere. The cereal production of the world, in bushels, is a little short of 5,000,000,000; the United States last year produced 1,500,000,000, of which ten Western States, including Kentucky, produced 1,000,000,000, or $\frac{1}{5}$ of that of the world. I became satisfied that 2,000,000 tons of the production of the great West fail to reach the Atlantic markets, worth, including transportation, at least $200,000,000; in other words—and because every dollar's worth of production sent to the seaboard buys another dollar's worth that is returned to the country—the Atlantic markets have lost $400,000,000, and the people of the West one-half that sum.

Referring to the question of difference between communication by rail and by water, I ascertained that the four trunk railways from the East to the West—the New York Central, the Erie, the Pennsylvania, and the Baltimore and Ohio, carried only one-fourth of all that came East; the remainder came over the Erie and Welland canals. In regard to the cost, the products of the country may be carried 1,000 miles by water almost as cheaply as 100 miles by land. Freights from Albany to New York are the same as from New York to Liverpool. From New York to San Francisco the rates per ton are—by the Pacific

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* Address by Hon. William J. McAlpine, before the Chamber of Commerce, at the Cooper Union

railroad, about 3,000 miles, from $60 to $100; by the Isthmus of Panama, about 7,000 miles, $20, and around Cape Horn, about 16,000 miles, but $12.

Railroads and canals are not antagonistic, they are parts of the same system and both indispensable. Railroads are required for the carriage of passengers, valuable parcels and perishable articles; but in this country they cannot be substituted for water conveyance. Who expects to see in his day the Erie Canal abandoned? The best talent and skill has been engaged in the management of railroads, which is not the case to any considerable degree with canals. To-day, steam has not yet been successfully tried on the Erie Canal, and boats are still towed by horses, as they were by the Ptolemies in Egypt 3,000 years ago. The ocean steamers have not yet taken the place of sailing vessels. Thirty-five or forty years ago the locomotive was imperfect, and its success was uncertain; it has been completed within a few years, comparatively, and now is the greatest machine of the age; the combined achievement of the superior intellects applied to its development.

Prof. Greene—I have given the subject of steam canal navigation some attention for the past two years. having been connected with a commission in New York, appointed to test the various plans proposed for introducing steam upon the Erie Canal. My estimates show that the cost, including all expenses, of moving boats by horse-power in the canal and on the Hudson river is about five mills per ton per mile. The cost of transportation by rail depends upon the grade, expense of construction and many other circumstances. On the principal trunk lines the cost at present seems to be about 1¼ cents per ton per mile.

I have made estimates to ascertain how far this might be reduced on lines devoted exclusively to the transportation of freight, where trains were moved without interruption or being laid up on side-tracks, and found that the minimum cost, including all items of expenditure, would be about 7¼ mills per ton per mile. The experiments made with steam upon the canals during the last two years show a reduction of cost, as compared with horse-power, of from 22 to 25 per cent.—based upon transportation from Buffalo to New York, by way of the Erie Canal and Hudson river. If steamers were used exclusively, this saving might possibly reach 50 per cent.

I have considered the different ways of towing. By the ordinary canal-boat, carrying its own machinery with 200 tons of freight, and towing two other boats of the same size carrying from 225 to 235 tons, the cost seems to be about the same as by that where the machinery is applied directly to each boat; the objection is that boats towed at the speed of three miles per hour become unmanageable, and captains will not take the consequent risk; even at 2½ miles per hour there is danger of injury by collision.

Where a tug-boat tows two or three loaded boats the cost is decidedly greater than if each boat carried its own machinery. The reasons are obvious: the tug-boat would at first cost as much as three or four ordinary canal boats. I cannot quote the figures, and will only suggest a line of investigation, whereby any person interested in this subject may arrive at a conclusion. Another reason is found in the application of the power. The size of the boat is determined by the size of the load. A single boat may carry and use as much propelling power as is required by those making up the tow; but there is always a certain loss from slip, which increases rapidly with the number of boats towed and the power expended, so that when three or four boats are towed, the loss may be 50, 60, and even 80 per cent.—that is, the power utilized may be only 20 per cent. instead of 50 to 70 per cent. as it should be.

Another objection to moving boats in tow is that much time is lost in lockage. A single boat may pass a lock in about five minutes; where there are two boats, one being towed after the other, the first will go through as quickly as a single one, but the second boat, having no power, will be twice as long, and the time thus lost will similarly increase for every additional boat towed, so that when there are four or five boats, a large part of the time required to make the trip will be spent at the locks, where the boatmen are idle, the power is useless, the fires are burning and the interest account is going on. Then again, a towed boat, having no power of its own, will not last as long as a boat having its own power, for the reason that it cannot avoid collisions.

I have given attention to the Belgian system, and would say, that while it is perhaps successful in Belgium, it could not be so here. It consists of a wire cable, laid in the bottom of the canal, which works over a clip dam operated by machinery. I understand that the Belgian canals, for the most part, are very straight and have few locks; on the contrary, American canals have many sharp curves and excessive lockage, both of which are serious obstacles to the successful introduction of such a system.

Mr. Shinn—I do not know that I can add any very precise information to that already possessed by the Convention on this subject, but I will make a few statements which, while they differ in some respects from those of gentlemen who precede me, may open a field for investigation. This subject of transportation is the question of the hour. During the past six months it has largely entered into the debates of Congress, occupied the time of State Legislatures, and been discussed in the meetings of farmers' granges, and by other assemblages. There is a demand to know whether transportation cannot be performed better and cheaper. Investigation has naturally caused discussion, and a great variety of views are put forth, most of which do not proceed from a scientific or professional source, or present facts which can be relied on to determine the real state of the question.

It has been said in this Convention that in this country railroads have received the attention of the best engineering minds—not in the broad sense, that to construct and maintain them the ablest engineers have in some capacity assisted, but that in railway management they have largely taken part. I think this is an error; surely those who are prominent in managing the principal railways are not noted as skilful engineers, but rather as successful manipulators of Legislatures, operators on Wall street, speculators who get up corners in stock and increase or depreciate nominal values. These are the men who control railroads—not by virtue of their ability as practical managers, but because they own stock, or possess the confidence of those who do. No men in this country are less likely to become either manipulators of Legislatures or victims of Credit Mobilier schemes than those of our profession; prominent engineers do not get up schemes of that kind either to run railroads or to build them. On the other hand, men who control and operate our railroads are not investigating the scientific basis on which the economy of transportation depends, or employing others to do so, and as a consequence the wildest notions prevail on the subject.

It is asserted by those who have looked into the matter somewhat, that it cost $1\frac{1}{2}$ cents per ton per mile to transport freight by rail. I am prepared to say that on the more important railroads of this country freight was transported at a profit last year for $\frac{7}{9}$ cent per ton per mile, and therefore the actual cost must have been less. The rate in 1872 for the transportation of fourth-class freight from Chicago to New York, was about 40 cents per 100 lbs., of which 5 cents was expended at New York to get it across the river and deliver it to vessels in the harbor; leaving 35 cents per 100 lbs., or $7.00 per ton received for transportation over 900 to 960 miles of railway. The roads which carried freight at this rate never made more money than last year, hence this business was not done at a loss, as it was a large proportion of the traffic. From this it is evident that the maximum cost was 7 mills per ton per mile; that, of course, was upon freight moved in full trains of loaded cars, and under circumstances most favorable to the present railway management.

Instead of the economy of railway transportation receiving the attention of the best engineering talent in the country, it seems to me that such talent has been studiously avoided, and rigorously excluded from any controlling voice in the management. Within my own knowledge, roads for years have been run with an equipment which was not more than two-thirds adequate to do the business pressing upon them. In this case the railway was a machine capable of doing twice or three times the business it was doing, but its equipment was insufficient to employ it more than one-third or one-half the time. In one instance, after frequent respresentations of this fact to the managers, an unusual pressure of business having convinced them that more equipment was needed, they suddenly increased it without making any corresponding extension of terminal facilities or side tracks, and then the machine was disproportioned the other way. There was nearly, perhaps quite enough equipment for the time, but sufficient terminal facilities to dispose of the traffic as fast as it arrived, and side tracks to allow the trains to pass without delay, were lacking, and so the business of the road was crippled by blockades at the terminus, and along the line. Where 400 cars per day should have been handled, not more than 100 got through; thus illustrating, in not an encouraging manner, the kind of engineering talent applied to some of our best railroads.

The capacity of railroads to do business, compared with canals, should not be judged by the amount done upon the four existing trunk lines, none of which, so far as I know, are managed upon a scientific basis. They are not generally controlled by men who value engineers, or employ them to do anything more than to locate the road, and, perhaps, construct some of the works. Hence these lines have been slow to develop the resources of the country, procure sufficient equipment, acquire necessary terminal facilities and adequate means at tidewater to dispose of what freight could be brought there. For instance, the Pennsylvania Railroad, which has the reputation of being one of the best managed railroads in the country, has been unable to get rid of more than 60 cars of grain, in bulk, per day, without being blocked up. The number of cars is not limited until they are really blocked, and then the blockade is transferred back from Jersey City to Philadelphia, and from Philadelphia to Pittsburgh, until every yard on the line from Jersey City to Chicago is full. The need of increased facilities at Jersey City has been for some time very evident, but the stockholders of the Camden and Amboy Railroad declined to spend $4,000,000 there to get rid of freight for the Pennsylvania Railroad, which they hauled only 90 miles. While the latter road would be greatly benefited by an expenditure of this sum in filling up docks, increasing depot facilities and building elevators, it manifestly would make no return to them, and therefore they would not appropriate it. This particular instance of a single defect in railway management will in due time be remedied.

It is true that a vast amount of agricultural products is not taken to the seaboard, but without doubt a much larger amount could be carried by existing roads if prices obtainable for it there would justify its shipment. Whether the price of these products can be reduced is mainly a question whether the cost of transportation can be lessened. As I have stated, in one case during the last year, this cost to the consumer, and not the railroad company, was from 7 to 8 mills per ton per mile, which I believe can be considerably reduced.

Take, for instance, the item of dead weight: A common well-built country wagon, weighing about 800 pounds, will carry 3,000 on any fair country road, and without injury pass over obstructions which cause it to fall one, two or more inches, the paying weight being about 79 per cent. of the whole. The ordinary box-car in use upon our railways at the present time weighs about 10 tons; its maximum load is generally about 11 tons, while its average load is about 8 tons; the paying weight being from 44 to 52 per cent. of the whole. It does not seem reasonable that the weight of a car constructed to run upon a smooth even track, without a fall, should be so disproportioned to the load carried. The proper relation and proportion to each other of the different parts of railway machinery is a subject worthy of consideration by the best engineers.

What amount of tonnage may be carried over a railroad is, to a great extent, a matter of speculation; but if, as has been already projected, a double-track railroad were exclusively used for a freight traffic, with its trains always running at a uniform speed, without turning out or laying over, it is manifest that many trains could be moved on the two tracks. The ordinary rule is for freight trains to follow each other 5 min. apart, but by the English block system, or a similar one, this may be reduced to 2 min. If 10 min. are allowed between trains, and the cars are of construction and engines of power so that each train will carry 200 tons (more than which is done on many railroads now), 1,200 tons would pass in one direction every hour. 1,000 tons per hour would be 24,000 tons a day, and 7,200,000 tons in a year of 300 working days, which is much more than was carried last year by the four trunk lines between the East and the West, as stated in this discussion. In an engineering point of view, there is nothing improbable in that. I will not attempt to compare the cost of carrying 7,000,000 tons on one railway with that of carrying 2,000,000 tons on four; evidently it would be much below the least sum already stated as the cost on one, if not all, of these four first-class railroads, namely, 7 mills per ton per mile.

A short time ago the "Pittsburgh Commercial," a paper that generally presents enlightened views, "in an article on this subject of transportation," suggested that if a railroad were devoted exclusively to freight traffic, and operated by parties who owned and run the cars they used (and by inference the locomotives also, although it was not so stated), the same as boats are now owned and run on the canals, the present cost to the consumer would be reduced three-fourths. Cereals grown in Iowa, Kentucky, Missouri, and other Western States, are transported to the seaboard, at an average cost for the whole year less than 1 cent per ton per mile, therefore this article assumed that it could be done for 2½ or 3 mills. Statements so far from fact fail to engage the attention of transporters, and lead to no good result.

A complete and authoritative investigation into the cost of transportation, made by intelligent parties, capable of deducing principles from established data, would not only be very instructive to engineers and railway managers, but of vast importance to the country at large. There is nothing of the kind now, nor can I suggest the source from whence any authoritative statement may be expected, unless it is this Society.

Mr. Rothwell—In regard to the utilization of waste coal, alluded to in the paper read, it may be said that engineers and railroad men are more interested in the consumption of coal than in the details of mining. What the quantity of that consumption shall be, depends much upon the cost of coal where it is used, which, of course, varies with the charges for freight, the amount of waste, and the expense of mining.

The waste of coal occurs either in mining, preparation for market, or transportation and storage. My estimates of the quantity lost in mining mostly refer to anthracite coal, though they would apply to the bituminous coal of this country; the two being generally mined on the same system—that of chambers and pillars, whereby a portion of the coal is taken out in rooms, and the remainder left to sustain the roof. In mines worked at moderate depths, up to 300 or 400 ft., and where consequently the pressure of the overlying strata is small, not less than 25 per cent. of the coal is left in pillars; probably 33 per cent. will nearly represent the average in mines of various depths.

A great portion of the 67 per cent. taken out is broken into sizes to suit the market. This has been done so long that consumers expect it, although usually the coal could be burned in lumps or broken where used, and the resulting waste avoided; for which, as well as the cost of breaking at the mines, the consumer, of course, has to pay. In preparing coal for market—that is, breaking, screening, and washing it—the waste varies from 15 to 45 per cent.; where crushers with sharp steel teeth, and other suitable machinery are used, this is much reduced, and perhaps 25 per cent. may be taken as an average loss from this cause. The fine coal in the anthracite region is thrown aside as useless. Attempts have been made to manufacture it into a compressed fuel, which was found to cost more than the coal in lumps.

Then there is the waste in transportation. Most of the coal cars used for transporting anthracite coal have high bodies, whence the shutes from which they are loaded are about 8½ ft. above the track; the coal falls from them to the bottom of the car, and consequently a portion of it is broken. It is then carried at considerable speed, especially where there is a down grade, over the roads, some of which are pretty rough. Experience shows that the breakage varies very much with the speed of the trains; in bituminous coal it is more apparent than in anthracite; and in either case there is a larger percentage broken in transportation than most engineers suppose. When there are different sizes of coal in the same car the smaller fills up between the larger, and a less quantity is crushed. This fine coal, if bituminous, can be readily used at the end of the route; a large part of the anthracite dust is sold, but at a reduced price, and the difference added to that of good marketable coal. Probably the form of cars could be changed so as to lessen this item of waste.

The loss in volatile matter—and even in fixed carbon—which coal, and particularly bituminous coal, undergoes, when allowed to heat in heaps exposed to the weather, amounts sometimes to 10, and possibly even 20 or more per cent. Coal should be kept dry, cool, and under cover—an important matter well worth the consideration of railroad managers.

These are the principal items of loss. This Society of Civil Engineers, perhaps, is not so much interested in the mining of coal as its transportation; still, whatever affects the cost in the market of this prime commodity should receive attention from railroad, scarcely less than from mining, engineers. The question of the waste of coal is being examined by a committee of our sister society—the American Institute of Mining Engineers, of which I have the honor to be a member; the committee has been more than a year engaged in collecting information, and, without doubt, the result of the investigation will have an important bearing upon the subject of mining and preparing coal.

Mr. McAlpine—I stated that ¾ of all the freight from the West to the tide water went by two canals—chiefly by the Erie; that left but 2,000,000 tons to be carried by the four trunk railroads altogether. Reports referred to in my address before the Chamber of Commerce, show how much was actually transported both ways; although the quantity of freight is large, during the year these roads together moved eastward only 2,000,000 tons of through freight, which is the class I alluded to.

I would mention that thirty years ago I ascertained the tonnage from the West to tide water by all the railways and water lines, to be nearly four times as much as that from tide water to the West, while the values of the two were nearly equal.

Mr. Shinn—The statements I made of the cost of transportation were not of that upon a model railroad, but based on the work actually done by existing railways during the past year; they were made after full deliberation, and result from due investigation. I am prepared to prove them, and when I can possibly find the time, I will do so in detail.

ON FUEL.*

By C. WILLIAM SIEMENS, D. C. L., F. R. S.

In accepting the invitation of the Council of the British Association to deliver an address to the operative classes of this great industrial district, I felt that I was undertaking no easy task. Having to speak on behalf of the Association, and in the presence of many of its most distinguished members, I am bound to treat my subject scientifically; but I have to bear in mind at the same time that I am addressing myself to men unquestionably of good intelligence, but without that scientific training which has almost created a language of its own.

It is no consolation for me to think that those who have taken a similar task upon themselves in former years, have admirably succeeded in divesting highly scientific subjects of the formalism in which they are habitually clothed. The very names of these men—Tyndall, Huxley, Miller, Lubbock, and Spottiswoode—are such as to preclude in me all idea of rivalry, but I hope to profit by their example, and to remember that truth must always be simple, and that it is only where knowledge is imperfect that scientific formulæ must take the place of plain statements.

The subject matter of my discourse is "Fuel;" a matter with which every one of us has become familiarized from his infancy, but which nevertheless is but little understood even by those who are most largely interested in its applications; it involves considerations of the highest *à priori* interest, both from a scientific and a practical point of view.

I purpose to arrange my subject under five pricipal heads:—

1. What is fuel?
2. Whence is fuel derived?
3. How should fuel be used?
4. The coal question of the day?
5. Wherein consists the fuel of the sun?

WHAT IS FUEL?

Some of you may have already said within yourselves that it is but wasted time to enlarge upon such a theme, since all know that fuel is coal drawn from the earth, from deposits, with which this country especially has been bountifully supplied; why disturb our plain understanding by scientific definitions which will neither reduce the cost of coal, nor make it last longer on our domestic hearth?

Yet I must claim your patience for a little, lest, if we do not first agree upon the essential nature of fuel, we may afterwards be at variance in discussing its origin and its uses, the latter at any rate being of practical interest, and a subject worthy of your most attentive consideration.

Fuel, then, in the ordinary acceptation

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* A Lecture delivered to the Operative Classes at Bradford on behalf of the British Association.

of the term, is carbonaceous matter, which may be in the solid, the liquid, or in the gaseous condition, and which, in combining with oxygen, gives rise to the phenomenon of heat. Commonly speaking, this development of heat is accompanied by flame, because the substance produced in combustion is gaseous. In burning coal, for instance, on a fire-grate, the oxygen of the atmosphere enters into combination with the solid carbon of the coal and produces carbonic acid, a gas which enters the atmosphere, of which it forms a necessary constituent, since without it, the growth of trees and other plants would be impossible. But combustion is not necessarily accompanied by flame, or even by a display of intense heat. The metal magnesium burns with a great display of light and heat, but without flame, because the product of combustion is not a gas but a solid, viz.; oxide of magnesium. Again, metallic iron, if in a finely divided state, ignites when exposed to the atmosphere, giving rise to the phenomena of heat and light without flame, because the result of combustion is iron oxide or rust; but the same iron, if presented to the atmosphere—more especially to a damp atmosphere—in a solid condition, does not ignite, but is nevertheless gradually converted into metallic oxide or rust as before.

Here, then, we have combination without the phenomena either of flame or light; but by careful experiment we should find that heat is nevertheless produced, and that the amount of heat so produced precisely equals that obtained more rapidly in exposing pulverulent iron to the action of oxygen. Only, in the latter case the heat is developed by slow degrees, and is dispersed as soon as produced, whereas in the former the rate of production exceeds the rate of dispersion, and heat, therefore, accumulates to the extent of raising the mass to redness. It is evident from these experiments that we have to widen our conception, and call fuel "any substance which is capable of entering into combination with another substance, and in so doing gives rise to the phenomenon of heat."

In thus defining fuel, it might appear at first sight that we should find upon our earth a great variety, and an inexhaustible supply of substances that might be ranged under this head; but a closer investigation will soon reveal the fact, that its supply is, comparatively speaking, extremely limited.

In looking at the solid crust of the earth, we find it to be composed for the most part of siliceous, calcareous, and magneceous rock; the former, silica, consisting of the metal silicon combined with oxygen, is not fuel, but rather a burnt substance which has parted with its heat of combustion ages ago; the second, limestone, being carbonate of lime, or the combination of two substances, viz., calcic oxide and carbonic acid, both of which are essentially products of combustion, the one of the metal calcium, and the other of carbon; and the third, magnesia, a combination of oxygen with the metal magnesium (which I have just burnt before you), and which, further combined with lime, constitutes dolomite rock, of which the Alps are mainly composed. All the commoner metals, such as iron, zinc, tin, aluminium, sodium, etc., we find in nature in an oxidized or burnt condition; and the only metallic substances that have resisted the intense oxidizing action that must have prevailed at one period of the earth's creation are the so-called precious metals, gold, platinum, iridium, and to some extent also silver and copper. Excepting these, coal alone presents itself as carbon and hydrogen in an unoxidzed condition. But what about the oceans of water, which have occasionally been cited as representing a vast store of heat-producing power ready for our use when coal shall be exhausted. Not many months ago, indeed, on the occasion of a water gas company being formed, statements to this effect could be seen in some of our leading papers. Nothing, however, could be more fallacious. When hydrogen burns, doubtless a great development of heat ensues, but water is already the result of this combustion (which took place upon our globe before the ocean was formed), and the separation of these two substances would take precisely the same amount of heat as was originally produced in their combustion. It will thus be seen that both the solid and fluid constituents of our earth, with the exception of coal, of naphtha (which is a mere modification of coal), and the precious metals, are products of combustion, and therefore the very reverse of fuel. Our earth may indeed be looked upon as "a ball of cinder, rolling unceasingly through space," but happily in company with another celestial body—the sun,—whose glorious beams are the physical cause of everything that moves and lives, or that has the power within itself of imparting life, or motion on our earth. This invigorating influence is made perceptible to our senses in the form of heat, but it is fair to ask, what is heat, that it should be capable of coming to us from the sun, and of being treasured up in our fuel deposits both below and on the surface of the earth?

If this inquiry had been put to me 30 years ago, I should have been much perplexed. By reference to books on Physical Science, I should have learnt that heat was a subtle fluid which, somehow or other, had taken up its residence in the fuel, and which, upon ignition of the latter, was sallying forth either to vanish or to abide elsewhere; but I should not have been able to associate the two ideas of combustion and development of heat by any intelligible principle in nature, or to suggest any process by which it could have been derived from the sun and petrified, or, as the empty phrase ran, rendered latent in the fuel.

It is by the labors of Mayer, Joule, and other modern physicists, that we are enabled to give to heat its true significance.

Heat, according to the "dynamical theory," is neither more nor less than motion amongst the particles of the substance heated, which motion, when once produced, may be changed in its direction and its nature, and thus be converted into mechanical effect, expressible in foot pounds, or horse power. By intensifying this motion among the particles, it is made evident to our visual organ by the emanation of light, which again is neither more nor less than vibratory motion imparted by the ignited substance to the medium separating us from the same. According to this theory, which constitutes one of the most important advances in science of the present century, heat, light, electricity, and chemical action are only different manifestations of "energy of matter," mutually convertible, but as indestructible as matter itself.

Energy exists in two forms, "dynamic" or "kinatic energy," or force manifesting itself to our senses as weight in motion, as sensible heat, or as an active electrical current; and "potential energy," or force in a dormant condition. In illustration of these two forms of energy, I will take the case of lifting a weight, say one pound one foot high. In lifting this weight kinatic, muscular energy has to be exercised in overcoming the force of gravitation of the earth. The pound weight when supported at the higher level to which it has been raised, represents "potential energy" to the amount of one unit or "foot pound." This potential energy may be utilized, in imparting motion to mechanism, during its descent, whereby a unit amount of "Work" is accomplished. A pound of carbon then, when raised through the space of one foot from the earth, represents, mechanically speaking, a unit quantity of energy, but the same pound of carbon when separated or, so to speak, lifted away from oxygen, to which it has a very powerful attraction, is capable of developing no less than 11,000,000 foot pounds or unit quantities of energy whenever the bar to their combination, namely, excessive depression of temperature, is removed; in other words, the mechanical energy set free in the combustion of 1 lb. of pure carbon is the same as would be required to raise 11,000,000* lbs. weight 1 ft. high, or as would sustain the work which we call a horse power during 5 hours 33 min. We thus arrive at once at the utmost limit of work which we can ever hope to accomplish by the combustion of 1 lb. of carbonaceous matter, and we shall presently see how far we are still removed in our practice from this limit of perfection.

The following illustrations will show the convertibility of the different forms of energy. If I let the weight of a hammer descend in rapid succession upon a piece of iron it becomes hot, and on beating a nail thus vigorously and skilfully for a minute it will be red-hot. In this case the mechanical force developed in the arm (by the expenditure of muscular fibre) is converted into heat. Again, in rapidly compressing the air in a fire syringe, ignition of a piece of tinder is obtained. Again, in passing an electrical current through the platinum wire it is directly converted into heat, which is manifested by ignition of the wire, whereas the thermopile gives an illustration of the conversion of heat into electricity; to which illustrations many others might be added. The heat of combustion being the result of the chemical combination of two substances, does it not follow that oxygen is a combustible as well

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* In burning 1 lb. of carbon in the presence of free oxygen, carbonic acid is produced and 14,500 units of heat (a unit of heat is 1 lb. of water raised through 1 deg. Fah.) are liberated. Each unit of heat is convertible (as proved by the deductions of Mayer and the actual measurements of Joule) into 774 units of force or mechanical energy; hence 1 lb. of carbon represents really 14,500×774=11,223,000 units of potential energy.

as the carbonaceous substance which goes by the name of fuel? This is, unquestionably, the case, and if our atmosphere was composed of a carbonaceous gas, we should have to conduct our oxygen through tubes and send it out through burners to supply us with light and heat, as will be seen by the experiment in which I burn a jet of atmospheric air in a transparent globe filled with common lighting gas; but we could not exist under such inverted conditions, and may safely strike out oxygen and analogous substances, such as chlorine, from the list of fuels.

We now approach the second part of our inquiry—

WHENCE IS FUEL DERIVED?

The rays of the sun represent energy in the form of heat and light, which is communicated to our earth through the transparent medium which must necessarily fill the space between us and our great luminary. If these rays fall upon the growing plant, their effect disappears from direct recognition by our senses, inasmuch as the leaf does not become heated as it would if it were made of iron or dead wood, but we find a chemical result accomplished, viz., carbonic acid gas, which has been absorbed by the leaf of the tree from the atmosphere, is there "dissociated," or separated into its elements, carbon and oxygen, the oxygen being returned to the atmosphere, and the carbon retained to form the solid substance of the tree.

The sun thus imparts 11,000,000 units of energy to the tree for the formation of 1 lb. of carbon in the shape of woody fibre, and these 11,000,000 units of energy will be simply resuscitated when the wood is burnt, or again combined with oxygen to form carbonic acid.

Fuel, then, is derived through solar energy acting on the surface of our earth.

But what about the stores of mineral fuel, of coal, which we find within its folds? How did they escape the general combustion which, as we have seen, has consumed all other elementary substances? The answer is a simple one. These deposits of mineral fuel are the results of primeval forests, formed in the manner of to-day, through the agency of solar rays, and covered over with earthy matter in the many inundations and convulsions of the globe's surface, which must have followed the early solidification of its surface. Thus our deposits of coal may be looked upon as the accumulation of potential energy derived directly from the sun in former ages, or as George Stephenson, with a sagacity of mind in advance of the science of his day, answered, when asked what was the ultimate cause of motion of his locomotive engine, "that it went by the bottled-up rays of the sun."

It follows from these considerations that the amount of potential energy available for our use is confined to our deposits of coal, which, as appears from the exhaustive inquiries lately made by the Royal Coal Commission, are still large indeed, but by no means inexhaustible, if we bear in mind that our requirements will be ever on the increase, and that the getting of coal will become from year to year more difficult as we descend to greater depth. To these stores must be reckoned lignite and peat, which, although not coal, are nevertheless the result of solar energy, attributable to a period of the earth's creation subsequent to the formation of the coal beds, but anterior to our own days. These fuels may be made as efficient as coal if properly treated.

In discussing the necessity of using our stores of fuel more economically, I have been met by the observation that we need not be anxious about leaving fuel for our descendants—that the human mind would surely invent some other source of power when coal should be exhausted, and that such a source would probably be discovered in electricity. I heard such a suggestion publicly made only a few weeks back at a meeting of the International Jury at Vienna, and could not refrain from calling attention to the fact that electricity is only another form of energy, that could no more be created by man than heat could, and involved the same recourse to our accumulated stores.

If our stores of coal were to ebb, we should have recourse, no doubt, to the force radiating from the sun from year to year, and from day to day; and it may be as well for us to consider what is the extent of that force, and what are our means of gathering and applying it. We have, then, in the first place the accumulation of solar energy upon our earth's surface by the decomposition of carbonic acid in plants, a source which we know by experience suffices for the human requirements in thinly populated countries, where industry has taken only a slight development. Wherever population accumulates, however, the wood of the forest no longer suffices even for domestic requirements, and mineral fuel has to be transported from great distances.

The sun's rays produce, however, other effects besides vegetation, and amongst these, that of evaporation is the most important as a source of available power. By the solar rays, an amount of heat is imparted to our earth that would evaporate yearly a layer of water 14 ft. deep. A considerable proportion of this heat is actually expended in evaporating sea water, producing steam or vapor, which falls back upon the entire surface of both land and sea in the form of rain. The portion which falls upon the elevated land flows back towards the sea in the form of rivers, and in its descent its weight may be utilized to give motion to machinery. Water power, therefore, is also the result of solar energy, and an elevated lake may indeed be looked upon as fuel, in the sense of its being a weight lifted above the sea level through its prior expansion into steam.

This source of power has also been largely resorted to, and might be utilized to a still greater extent in mountainous countries; but it naturally so happens that the great centres of industry are in the plains, where the means of transport are easy, and the total amount of available water-power in such districts is extremely limited.

Another result of solar energy are the winds, which have been utilized for the production of power. This source of power is, indeed, very great in the aggregate, but its application is attended with very great inconvenience. It is proverbial that there is nothing more uncertain than the wind, and when we were dependent upon windmills for the production of flour, it often happened that whole districts were without that necessary element to our daily existence.

Ships also, relying upon the wind for their propulsion through the sea, are often becalmed for weeks, and so gradually give place to steam-power on account of its greater certainty. It has been suggested of late years to utilize the heat of the sun by the accumulation of its rays into a focus by means of gigantic lenses, and to establish steam-boilers in such foci. This would be a most direct utilization of solar energy, but it is a plan which would hardly recommend itself in this country, where the sun is but rarely seen, and which even in a country like Spain would hardly be productive of useful practical results.

There is one more natural source of energy available for our uses, which is rather cosmical than solar—viz., the tidal wave. This might also be utilized to a very considerable extent in an island country, facing the Atlantic seas, like this, but its utilization on a large scale is connected with great practical difficulty and expenditure, on account of the enormous area of tidal basin that would have to be constructed.

In passing in review these various sources of energy which are still available to us, after we have run through our accumulated capital of potential energy in the shape of coal, it will have struck you that none of them would at all supply the place of our willing and ever-ready slave—the steam-engine; nor would they be applicable to our purposes of locomotion, although means might possibly be invented of storing and carrying potential energy in other forms. But it is not force alone that we require, but heat for smelting our iron and other metals, and the accomplishment of other chemical processes. We also need a large supply for our domestic purposes. It is true that with an abundant supply of mechanical force we could manufacture heat, and thus actually accomplish all our purposes of smelting, cooking, and heating, without the use of any combustible matter; but such conversion would be attended with so much difficulty and expenditure that one cannot conceive human prosperity under such laborious and artificial conditions.

We come now to the question—

HOW SHOULD FUEL BE USED?

I propose to illustrate this by three examples which are typical of the three great branches of consumption:

a. The production of steam power.
b. The domestic hearth.
c. The metallurgical furnace.

Steam Engine Consumption.—I have represented on a diagram two steam cylinders of the same internal dimensions, the one being what is called a high-pressure steam cylinder, provided with the ordinary slide valve for the admission of steam and its subsequent discharge into the atmosphere, and the other so arranged as to use the steam expansively (being provided with the Corliss variable expansion gear) and working in connection with a condenser. I have also shown two diagrams of the steam pressures at each part of the stroke, assuming in both cases the same initial steam pressure of 60 lbs. per square inch above the atmospheric pressure, and the same load upon the engine. They show that in the latter case the same amount of work is accomplished by filling the cylinder, roughly speaking, up to $\frac{1}{3}$ part of the length as in the other by filling it entirely. Here we have then an easy and feasible plan of saving $\frac{2}{3}$ of the fuel used in working an ordinary high-pressure engine, and yet probably the greater number of the engines now actually at work are of the wasteful type. Nor are the indications of theory in this case (or in any other when properly interpreted) disproved by practice; on the contrary, an ordinary non-expansive non-condensing engine requires commonly a consumption of from 10 to 12 lbs. per horse power per hour, whereas a good expansive and condensing engine accomplishes the same amount of work with 2 lbs. of coal per hour, the reason for the still greater economy being, that the cylinder of the good engine is properly protected by means of a steam jacket and lagging against loss by condensation within the working cylinder, and that more care is generally bestowed upon the boiler and the parts of the engine, to insure their proper working condition.

A striking illustration of what can be accomplished in a short space of time was brought to light by the Institute of Mechanical Engineers, over which I have at present the honor to preside. In holding their annual general meeting in Liverpool in 1863, they instituted a careful inquiry into the consumption of coal by the best engines in the Atlantic Steam Service, and the result showed that it fell in no case below $4\frac{1}{2}$ lbs. per indicated horse power per hour. Last year they again assembled with the same object in view, in Liverpool, and Mr. Bramwell produced a table showing that the average consumption by 17 good examples of compound expansive engines did not exceed $2\frac{1}{4}$ lbs. per indicated horse power per hour. Mr. E. A. Cowper has proved a consumption as low as $1\frac{1}{2}$ lbs. per indicated horse power per hour in a compound marine engine, constructed by him with an intermediate superheating vessel. Nor are we likely to stop long at this point of comparative perfection, for in the early portion of my address I have endeavored to prove that theoretical perfection would only be attained if an indicated horse power were produced with $\frac{1}{5.5}$ lb. pure carbon, or say $\frac{1}{4}$ lb. of ordinary steam coal per hour.

Here then we have two distinct margins to work upon, the one up to the limit of say 2 lbs. of coal per horse power per hour, which has been practically reached in some and may be reached in most cases, and the other up to the theoretical limit of $\frac{1}{4}$ lb. per horse power per hour; which can never be absolutely reached, but which inventive power may and will enable us to approach!

Domestic Consumption.—The wastefulness of the domestic hearth and kitchen fire is self-evident. Here only the heat radiated from the fire itself is utilized, and the combustion is generally extremely imperfect, because the iron back, and excessive supply of cold air, check combustion before it is half completed. We know that we can heat a room much more economically by means of a German stove, but to this it may be very properly objected that it is cheerless because we do not see the fire or feel its drying effect upon our damp clothing; moreover, it does not provide in a sufficient degree for ventilation, and makes the room feel stuffy. These are, in my opinion, very weighty objections, and economy would not be worth having if it could only be obtained at the expense of health and comfort. But there is at least one grate that combines an increased amount of comfort with reasonable economy, and which, although accessible to all, is as yet very little used. I refer to Captain Galton's "Ventilating Fireplace," of which you observe a diagram upon the wall. This fireplace does not differ in external appearance from an ordinary grate, except that it has a higher brick back, which is perforated at about midheight to admit warmed air into the fire so as to burn a large proportion of the smoke which is usually sent up the chimney unburnt, for no better purpose than to poison the atmosphere which we have to breathe.

The chief novelty and merit of Captain Galton's fireplace consists, however, in providing a chamber at the back of the grate, into which air passes directly from without, becomes moderately heated (to 84 deg. Fah.), and, rising in a separate flue, is injected into the room under the ceiling with a force due to the heated ascending flue. A plenum of pressure is thus established within the room whereby indraughts through doors and windows are avoided, and the air is continually renewed by passing away through the fireplace chimney as usual. Thus the cheerfulness of an open fire, the comfort of a room filled with fresh but moderately warmed air, and great economy of fuel, are happily combined with unquestionable efficiency and simplicity; and yet this grate is little used, although it has been fully described in papers communicated by Captain Galton, and in an elaborate report made by General Morin, lė Directeur du Conservatoire des Arts et Metiers of Paris, which has also appeared in the English language.

The slowness with which this unquestionable improvement finds practical application is due, in my opinion, to two circumstances,—the one is, that Captain Galton did not patent his improvement, which makes it nobody's business to force it into use, and the other may be found in the circumstance that houses are, to a great extent, built only to be sold and not to be lived in. A builder thinks it a good speculation to construct a score of houses after a cheap design, in order to sell them, if possible, before completion, and the purchaser immediately puts up the standard bill of "Desirable Residences to Let." You naturally would think that in taking such a house you had only to furnish it to your own mind, and be in the enjoyment of all reasonable creature comfort from the moment you enter the same. This fond hope is destined, however, to cruel disappointment; the first evening you turn on the gas, you find that although the pipes are there, the gas prefers to pass out by the joints into the room instead of by the burners; the water in like manner takes its road through the ceiling, bringing down with it a patch of plaster on to your carpet. But, worst of all, the products of combustion from the firegrates (made probably to dimensions irrespective of the size of the room), stoutly refuse to avail themselves of the chimney flues, preferring to disperse themselves in volumes of smoke into the room. Plumbers and chimney doctors are now put into requisition, pulling up floors, dirtying carpets, and putting up gaunt-looking chimney-pots; the grates themselves have to be altered again and again, until by slow degrees the house becomes habitable in a degree, although you now only become fully aware of the innumerable drawbacks of the arrangements adopted. Nevertheless, the house has been an excellent one "to sell," and the builder adopts the same pattern for another block or two in an increasing neighborhood. Why should this builder adopt Captain Galton's fireplace? It will not cost him much, it is true, and it will save the tenant a great deal in his annual coal bill, not to speak of the comfort it would give him and his family; but nobody demands it of him, it would give him some trouble to arrange his details and subcontracts, which are all settled beforehand, and so he goes on building and selling houses in the usual routine way. Nor will this state of things be altered until the dwellers in houses will take the matter in hand, and absolutely refuse to put up with builders' ways, or, what is still better, get builders who will put up houses in their way. This is done to some extent by building societies, but there is as yet too much of the old leaven left in the trade, and the question itself is too little understood.

Consumption in Smelting Operations.—We now come to the third branch of consumption, the smelting or metallurgical furnace, which consumes about 40,000,000 of the 120,000,000 tons of the coal produced. Here also is great room for improvement; the actual quantity of fuel consumed in heating a ton of iron up to the welding point, or in melting a ton of steel, is more in excess of the theoretical quantity required for these purposes than is the case with regard to the production of steam power and to domestic consumption. Taking the specific heat of iron at .114 and the welding heat at 2,900 deg. Fahrenheit, it would require .114×2,900=331 heat units to heat 1 lb. of iron. A pound of pure carbon develops 14,500 heat units, a pound of common coal say 12,000, and therefore one ton of coal should bring 36 tons of iron up to the welding point. In an ordinary reheating furnace a ton of coal heats only $1\frac{2}{3}$ ton of iron, and therefore produces only $\frac{1}{20}$ part of the maximum theoretical effect. In melting one ton of steel in pots $2\frac{1}{2}$ tons of coke are consumed, and taking the melting point of steel at 3,600 deg. Fahrenheit, the specific heat at .119, it takes .119×3,600=428 heat units to melt a pound of steel, and taking the heat-producing power of common coke also at 12,000 units, one ton of coke ought to be able to melt 28 tons of steel. The Sheffield pot steel melting furnace therefore only utilizes $\frac{1}{70}$th part of the theoretical heat developed in the combustion. Here therefore is a very wide margin for improvement, to which I have specially devoted my attention for many years, and not without the attainment of useful results. Since the year 1846, or very shortly after the first announcement of the dynamical theory, I have devoted my attention to a realization of some of the economic results which that theory rendered feasible, fixing upon the regenerator as the appliance which, without being capable of reproducing heat when once really consumed, is extremely useful for temporarily storing such heat as cannot be immediately utilized, in order to impart it to the fluid or other substance which is employed in continuation of the operation of heating, or of generating force.

Without troubling you with an account of the gradual progress of these improvements, in which my brother Frederick has taken an important part, I will describe to you shortly the furnace which I now employ for melting steel. It consists of a bed made of very refractory material, such as pure silica, sand and silica or Dinas brick under which 4 regenerators (or chambers filled with checkerwork of brick) are arranged in such a manner, that a current of combustible gas passes upward through one of these regenerators, while a current of air passes upwards through the adjoing regenerator, in order to meet in combustion at the entrance into the furnace chamber. The products of combustion, instead of passing directly to the chimney as in an ordinary furnace, are directed downwards through the two other regenerators on their way towards the chimney, where they part with their heat to the checkerwork in such manner that the highest degree of heat is imparted to the upper layers, and that the gaseous products reach the chimney comparatively cool (about 300 deg. Fah.). After going on in this way for half an hour, the currents are reversed by means of suitable reversing valves, and the cold air and combustible gas now enter the furnace chamber, after having taken up heat from the regenerators in the reverse order in which it was deposited, reaching the furnace therefore nearly at the temperature at which the gases of combustion left the same. A great accumulation of temperature within the regenerators is the result, one pair being heated while the other pair is being cooled; it is easy to conceive that, in this way, heat may be produced within the furnace chamber up to an apparently unlimited degree, and with a minimum amount of chimney draught.

Practically the limit is reached at the point where the materials composing the furnace chamber begin to melt. Whereas a theoretical limit also exists in the fact that combustion ceases at a point which has been laid down by St. Clair Deville at 4,500 deg. Fah., and which has been called by him the point of "dissociation." At this point hydrogen might be mixed with oxygen and yet the two would not combine, showing that combustion really only takes place btween the limits of temperature of about 600 and 4,500 deg. Fah.

To return to the regenerative gas furnace. It is evident that there must be economy where, within ordinary limits, any degree of heat can be obtained, while the products of combustion pass in the chimney only 300 deg. hot. Practically a ton of steel is melted in this furnace with 12 cwt. of small coal consumed in the gas producer, which latter may be placed at any reasonable distance from the furnace, and consists of a brick chamber containing several tons of fuel in a state of slow disintegration. In large works, a considerable number of these gas-producers are connected by tubes or flues with a number of furnaces. Collateral advantages in this system of heating are, that no smoke is produced, and that the works are not encumbered with solid fuel and ashes.

It is a favorite project of mine, which I have not had an opportunity yet of carrying practically into effect, to place these gas producers at the bottom of coal-pits. A gas shaft would have to be provided to conduct the gas to the surface, the lifting of coal would be saved, and the gas in its ascent would accumulate such an amount of forward pressure that it might be conducted for a distance of several miles to the works or places of consumption. This plan, so far from being dangerous, would insure a very perfect ventilation of the mine, and would enable us to utilize those waste deposits of small coal (amounting on the average to 20 per cent.) which are now left unutilized within the pit.

Another plan of the future which has occupied my attention is the supply of towns with heating gas for domestic and manufacturing purposes. In the year 1863 a company was formed, with the concurrence of the Corporation of Birmingham, to provide such a supply in that town at the rate of 6d. per 1,000 cubic ft.; but the Bill necessary for that purpose was thrown out in Committee of the House of Lords because their Lordships thought that if this was as good a plan as it was represented to be, the existing gas companies would be sure to carry it into effect. I need hardly say that the existing companies have not carried it into effect, having been constituted for another object, and that the realization of the plan itself has been indefinitely postponed. It has, however, lately been taken up and partly carried into effect at Berlin.

COAL QUESTION.

Having now passed in review the principal applications of fuel, with a view chiefly to draw the distinction between our actual consumption and the consumption that would result if our most improved practice were made general; and having, moreover, endeavored to prove to you what are the ultimate limits of consumption which are absolutely fixed by theory, but which we shall never be able to realize completely, I will now apply my reasoning to the coal question of the day.

In looking into the "Report of the Select Committee appointed to Inquire into the Causes of the Present Dearness of Coal," we find that in 1872 no less than 123,000,000 tons of coal was got up from the mines of England and Wales, notwithstanding famine prices and the colliers' strikes. In 1862 the total getting of coal amounted to only 83,500,000, showing a yearly average increase of production of 4,000,000 tons. If this progressive increase continues, our production will have reached, 30 years hence, the startling figure of 250,000,000 tons per annum; which would probably result in an increase of price very much in excess of the limits yet reached. In estimating last year's increase of price, which has every appearance of being permanent, at 8s. per ton all round, and after deducting the 13,000,000 tons which were exported abroad, we find that the British consumer had to pay £44,000,000 more than the market value of former years for his supply of coal—a sufficient sum, one would think, to make him look earnestly into the question of "waste of fuel," which, as I have been endeavoring to show, is very great indeed. The Select Committee just quoted sums up its report by the following expression:—

"The general conclusion to be drawn from the whole evidence is, that though the production of coal increased in 1872 in a smaller ratio than it had increased in the years immediately preceding, yet if an adequate supply of labor can be obtained, the increase of production will shortly keep pace with that of the last few years."

This is surely a very insufficient conclusion to be arrived at by a Select Parliamentary Committee after a long and expensive inquiry, and the worst of it is, that it stands in direct contradiction with the corrected table given in the same report, which shows that the progressive increase of production has been fully maintained during the last two years, having amounted to 5,826,000 for 1871, and 5,717,000 for 1872; whereas the average increase during the last ten years has only been 4,000,000 tons! It is to be hoped that Parliament will not rest satisfied with such a negative result, but will insist upon knowing whether a proper balance between the demand and supply of coal cannot be re-established, also what can be done to prevent the wholesale conversion of fuel into useless or positively hurtful results.

In taking the 105,000,000 tons of coal consumed in this country last year for our basis, I estimate that, if we could make up our minds to consume our coal in a careful and judicious manner, according to our present lights, we should be able to reduce that consumption by 50,000,000 tons. The realization of such an economy would certainly involve a very considerable expenditure of capital and must be a work of time; but what I contend is, that our progress in effecting economy ought to be accelerated, in order to establish a balance between the present production and the ever-increasing demand for the effects of heat.

In looking through the statistical returns of the progressive increase of population, of steam power employed, and of production of iron and steel, etc., I find that our necessities increase at a rate of not less than 8 per cent. per annum, whereas our coal consumption increases only at the rate of 4 per cent., showing that the balance of 4 per cent. is met by what may be called our "intellectual progress." Now, considering the enormous margin for improvement before us, I contend that we should not be satisfied with this rate of intellectual progress, involving, as it does, an annual deficit of 4,000,000 tons to be met by increased coal production, but that we should bring our intellectual progress up to the rate of our industrial progress, by which means we should make the coal production nearly a constant quantity for several generations to come. By that time our successors may be expected to have effected another great step in advance towards the theoretical limit of effect, which, as we have seen, lays so far above any actual result we have as yet attained, that an annual consumption of 10-000,000 tons would give more than the equivalent of the heat energy which we actually require.

SOLAR HEAT.

I have endeavored to show, in the early part of this lecture, that all available energy upon the earth, excepting the tidal wave, is derived from the sun, and that the amount of heat radiated year by year upon our earth, could be measured by the evaporation of a layer of water 14 ft. deep spread over the entire surface, which again would be represented by the combustion of a layer of coal 8 in. in thickness, covering our entire globe. It must, however, be taken into account that three-fourths of this heat is intercepted by our atmosphere, and only one-fourth reaches the earth itself. The amount of heat radiated away from the sun would be represented by the annual combustion of a thickness of coal 17 miles thick, covering its entire surface, and it has been a source of wonderment with natural philosophers how so prodigious an amount of heat could be given off year after year without any appreciable diminution of the sun's heat having become observable.

Recent researches with the spectroscope, chiefly by Mr. Norman Lockyer, have thrown much light upon this question. It is now clearly made out that the sun consists near the surface, if not throughout its mass, of gaseous elementary bodies, and in a great measure of hydrogen gas, which cannot combine with the oxygen present, owing to an excessive elevation of temperature (due to the original great compression), which has been estimated at from 20,000 deg. to 22,000 deg. Fah. This chemically inert and comparatively dark mass of the sun is surrounded by the photosphere, where its gaseous constituents rush into combustion, owing to reduction of temperature in consequence of their expansion and of radiation of heat into space. This photosphere is surrounded in its turn by the chromosphere, consisting of the products of combustion, which, after being cooled down through loss of heat by radiation, sink back, owing to their acquired density, towards the centre of the sun, where they become again intensely heated through compression, and are "dissociated" or split up again into their elements at the expense of internal solar heat. Great convulsions are thus continually produced upon the solar surface, resulting frequently in explosive actions of extraordinary magnitude, when masses of living fire are projected a thousand miles or more upward, giving rise to the phenomena of sun spots and of the corona which is visible during the total eclipses of the sun. The sun may therefore be looked upon in the light of a gigantic gas-furnace, in which the same materials of combustion are used over and over again.

It would be impossible for me at this late hour to enter further upon speculations regarding the "regeneration of the sun's heat upon its surface," which is a question replete with scientific and also practical interest. We should always remember that nature is our safest teacher, and that in trying to comprehend the great works of our Creator we shall learn how to utilize to the best advantage those stores of potential energy in the shape of fuel which have providentially been placed at our disposal.

A NOTE ON THE RESISTANCE OF MATERIALS.*

By Prof. ROBERT H. THURSTON.

On the 13th ultimo, an apparatus for determining the torsional resistance of materials, which I had designed for use, in illustration of my course of instruction, and to which I had fitted an automatic recording attachment, was exhibited to the National Academy of Science, at the late session held at this place, for the purpose of showing the peculiar adaptability of

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* A paper read before the American Society of Civil Engineers.

the machine for the determination and analysis of the action of physical and molecular forces in resisting stress, and to illustrate the bearing of experiments already made upon scientific investigations of molecular relations.

At the close of the meeting, a test piece of wrought-iron was left in the machine, exposed to a strain which had passed the limit of elasticity, and with a distortion of 45 deg., the intention being to determine whether, as has been suspected by some writers and by many engineers, "viscosity" is a property of solids, whether a "flow of solids"* could occur under long continued strain just equilibrating, when first applied, the resisting power of the material, or whether the "polarity" of Professor Henry is an absolutely unrelaxing force.

The metal was left under strain 24 hours, and had not then yielded in the slightest degree. This result, and the results of other similar experiments since made confirming it, indicates, that metal strained far beyond the limit of elasticity, as above described, does not lose its power of resisting unintermitted static stress.

The important bearing of this fact upon the availability of iron, and of steel, which also behaves similarly, for use in constructions exposed to severe strains, is readily seen.

After noting the result obtained as stated, it was attempted to still further distort the test piece, when the unexpected discovery was made that its resisting power was greater than when left the previous day, an increase of resistance being recorded amounting to about 25 per cent. of the maximum registered the preceding day, and approximating closely to the ultimate resistance of the material. Repeated experiments, continued up to the date of writing, confirm the following previously undemonstrated principle: that iron and steel if strained beyond the limit of elasticity, and left under the action of the distorting force which has been found just capable of equilibrating their power of resistance, gain resisting power to a degree which has a limit in amount, approximating closely, if not coinciding with the ultimate resistance of the material, and which had a limit, as to time, in experiments hitherto made, of 3 or 4 days.

Releasing the piece entirely and again submitting it to the same force immediately, does not produce this strengthening action.

There is some evidence, that is confirmed by theoretical dynamic principles, that the increase of strength noted is not accompanied by a change of resilience, but that the gain of resisting power is at the expense of a proportional amount of ductility.

The diagrams obtained during this research will be presented at a future time, when the investigation shall have been completed.

The interest and importance attaching to the discovery of the principles above enunciated, to our profession as well as to science, will, I hope, justify the presentation of this note.

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* Mon. H. Tresca; Sur l'Ecoulement des Corps Solides. Paris, 1869–72.

THE MANUFACTURE OF COMPRESSED-STONE BRICKS.*

By J J. BODMER, of London.

From "The Engineering and Mining Journal."

The substances or materials employed in this manufacture, are the same as those used in the preparation of mortar and concrete, viz.: the different kinds of lime and sand. Instead of, or in conjunction with sand there may be used calcined clay, blast-furnace slag, clinkers or ashes from furnaces, natural puzzolana, powdered chippings from stone quarries, etc. Of the different kinds of sand, pit sand—silicious sand, as it commonly occurs mixed with gravel—and the sand found on the sea-shore, where the salt has been washed out by long exposure, whilst out of reach of the tide, may be used. The purer the above-named materials are from admixtures of clay, earth, or organic substances, the more complete will be their combination with the lime, the quicker will the manufactured brick or block set, and the more satisfactory will be the quality which it ultimately attains. For this reason, subdivided blast-furnace slag is preferable in most

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* A paper read before the American Institute of Mining Engineers, at Easton, Pa., Oct. 22, 1873.

cases to sand, and the only sand which in reference to setting capacity is analogous to blast-furnace slag, is the volcanic sand occurring in different localities in North and South Wales as an almost pure calcined silica. The lime used for the manufacture may be either slaked or unslaked. In the first case (slaked), in order to obtain satisfactory results, the lime must be strongly hydraulic. The use of unslaked lime, however, is by far preferable. A process for using fresh or unslaked lime has been patented in England, by Major-General Scott. Lime thus prepared is called "selenitic lime," and consists of a mixture of fresh (unslaked) lime with sulphate of lime, or plaster of Paris. The grey stone lime, for instance, found by the Medway, is mixed with from 5 to 7 per cent. of plaster, which has the effect of keeping the lime from slaking when water is added. This mixture also partakes of the nature of cement, and when used for mortar or concrete, attains in a shorter time a greater degree of hardness than the same lime would ever have obtained after being slaked.

Bodmer's process for the manufacture of artificial stone bricks consists chiefly in the use of automatic measuring, forwarding, and mixing apparatus, by means of which the materials are supplied and unite in a continuous stream, and are accurately measured. They are then mixed and amalgamated automatically in a very perfect manner. Both the lime and the plaster are used in the form of powder. Supposing that two kinds of lime are used, besides plaster, each of these substances is fed into a separate hopper, from which they drop into a measuring apparatus. The outflow and speed of this apparatus is so arranged that, for instance, 80 per cent. of one kind of lime may be fed out during the time in which 20 per cent. of the other kind and 5 per cent. of plaster are delivered.

The stream formed by the three materials then flows into a dry mixing apparatus, in which a most perfect amalgamation of the particles takes place. Issuing from this, it is made to pass through a pair of rolls, going at differential speed, which grind up and rub the particles into each other. The sand, or subdivided slag, is fed into a similar measuring apparatus, from which it issues in a uniform layer on an endless india-rubber belt.

The proportions of sand, or slag, and lime depend chiefly upon the quality of the latter, and may consist of 5 to 8 lbs. or more of sand or slag to 1 lb. of the lime mixture. The lime mixture drops from the rolls upon the travelling layer of sand, or slag (which has been moistened as required, by a watering apparatus), and the several ingredients are made to travel into a mixing drum, and from that to a final amalgamating apparatus. From this last named apparatus the now finished mixture is carried by a belt to the press.

There are three methods of mixture :—

1. *Dry Mixture.*—In this process just as much water is added as is required for complete mixture of the sand and lime, so that on pressure being applied, no moisture is given off. But each grain of sand, or slag, must have its coating or skin of lime.

2. *Half-wet Mixture.*—In this process an excess of water is added; the mass is allowed to lie till this excess is absorbed; and before the mixture begins to set, it is fed into the press. The coating of each particle of sand, or slag, with lime, is in this case more certain and complete, and this process, under certain conditions, possesses many advantages over the foregoing. The dry mixture, however, is more convenient to work, and is giving most satisfactory results.

3. *Wet Mixture.*—In this process still more water is added, and the mixture is simply filled into moulds, or used for mortar and allowed to set without pressure. If instead of, or in conjunction with, lime, cement is used in order to quicken the hardening process, this method (wet mixing) is preferable for forming large blocks, etc.

Pressing.—For the forming or pressing of the bricks a hydraulic press is used, which is supplied by a pump and accumulator. The press has a horizontal turntable, in which there are six pairs of moulds. While two pairs are being filled, by means of a hopper, two others are under pressure; and the last two pairs deliver finished bricks on the surface of the table, from which they are taken off, put on barrows and carried out to the shed, or into the yard, where they are piled up and left until required for use.

From 6 to 8 weeks are required for the hardening of sand and lime bricks. The time depends chiefly on the quality of the sand and lime, and partly on the weather.

The hardening process goes on for years, and the difference in hardness may be observed from month to month.

The before-mentioned press is calculated for seven strokes per minute, that is to say, for a production of 28 bricks per minute. A pressure of 10 cwt. per sq. in., or 20 tons per brick of 9×4½×2¾ in., is found sufficient.

Two men and four boys are required for the whole of the manufacturing process. The number of hands for wheeling and piling the bricks depends upon the distance of the press from the shed or field where the bricks are deposited.

The same principle of press is applicable in the manufacture of bricks from common clay or fire clay; as also for fuel-bricks, asphalt-bricks, and many other descriptions of compressed materials.

Comparative Absorption Tests of Bodmer & Co.'s Patent Stone Bricks and of Clay Bricks.

	Best Gault Clay Bricks.	Best Stock Clay Brick.	Sand and Lime. Brick.	Blast furnace Dry Slag.	Slag and Lime Spongy Slag.
	lb. oz.	lb. oz.	lb. oz.	lb. oz.	lb. oz.
Weighed dry	5 15	4 13	6 9¾	7 7½	5 7¾
Weighed wet........	7 2¼	5 14½	7 1¼	7 12¼	5 14½
Water taken up per brick....	1 3¼	1 1½	0 7½	0 4¾	0 6¾
Percentage of water taken up.......	20.26	22.72	7.09	3.97	7.69

The bricks were dried on a heated iron plate and then weighed. They were then immersed for 50 hours in water and again weighed.

Cost of Manufacture of Blast-furnace Slag Bricks in Materials and Wages.

BODMER'S PATENT.

Blast-furnace Slag.		Sifted Lime.		Wages.		Total cost of 1,000 bricks.	Cost of Sub-dividing Slag.	
Per ton.	Per 1,000 bricks.	Per ton.	Per 1,000 bricks.	Per week.	Per 1.000 bricks.			Per week.
s. d	s d.	s. d.	s. d.	s. d.	s. d.	s. d.	One 4 h. p. engine at 5 lb. per hour per h. p. Coal at 20s. per ton	£1 10 0
0 6	1 3½	27 0	10 9½	169 2	2 1½	14 2½	Wages: 1 man by day, " 1 " night, at 24 s.....	2 8 0
0 6	1 3½	25 0	10 0	"	2 1½	13 5		3 18 0
0 6	1 3½	22 0	8 9½	"	2 1½	12 2½	240 tons of slag at 6d. per ton....	6 0 0
0 6	1 3½	20 0	8 0	"	2 1½	11 5		
0 6	1 3½	18 0	7 2	"	2 1½	10 7	Profit per week on slag used.................	2 2 0
0 6	1 3½	16 0	6 4¾	"	2 1½	9 9¾		
0 6	1 3½	14 0	5 7	"	2 1½	9 0	80,000 bricks per week.	per press.

The slag is supposed to be delivered in a sub-divided condition at the brick works.

Weight of bricks about 3 tons per 1,000.

Mixture, 52 cwt. slag with 8 cwt. of lime.

Wages calculated upon 2 men at 5d. per hour, 58 hours per week.

Ten boys at 2½d. per hour, 58 hours per week.

BRICK ARCHITECTURE.

From "The Builder."

The order given by the Egyptian taskmasters to the Israelites, is in substance echoed just now by some active professional practitioners,—"they say unto us, 'make brick'": in other words, there seems to be a decided leaning in certain quarters towards the employment of brick, not as an economical substitute for, but in preference to, stone. Whether this is the consequence or the cause of some of the studies that have been directed to the architecture of countries where brick is necessarily the staple building material, it is not very easy to say; we should be inclined to think it is rather the former. We have studied and more or less imitated, or adapted, most varieties of European work of the great architectural epoch, so far as style is concerned; and a material hitherto comparatively little used in high class architecture among ourselves, but which in some countries has been so almost exclusively employed as to give its own decided stamp and character to the architecture embodied in it, seems to promise a further change, and suggests new combinations of old things. The discussion which has taken place thereupon is indicative, along with other things, of the wish to find some degree of novelty of architectural expression in the revival or transplantation of some of the feeling of an essentially brick architecture.

From one point of view, certainly, it might be urged that we can have no need to go to other countries to study this class of architecture, when we have a brick architecture, pure and simple, so peculiarly our own, omitting notice of earlier work in this material, filling so many leagues of our streets with its unadorned neatness, and rising to something of monumental grandeur and dignity in the masses of warehouse and factory, to be found in different parts of the kingdom; heaps of bricks, as Fielding somewhere observes, piled up as a kind of token or monument that heaps of money had been piled first. It is all very well to sneer at the "hole-in-the-wall style," but it has at least been a great fact; it is the expression of the sole and comprehensive idea of thousands, we might say millions of people, as to the possibility of architectural expression in the exterior of city, and even of many country, homes; it represents, in one point of view, the readiest, simplest, and most economical way of using a material which can be formed into unlimited numbers of cubes of exactly the same size and proportion; and its merits in its palmy days have attracted the commendation, the sympathetic admiration of a very eminent modern philosopher. It has the quality, specially characteristic of the grandest production of the art, unity and breadth of style; like the Doric temple, it achieves effect by a repetition of similar features; and any section of it, taken separately, is, as a composition, complete in itself. The researches of modern architectural critics, however, are tending to throw contempt on this chaste and severe style of brick architecture, and drawing our attention more and more to the effects produced in other countries by moulded bricks, and tracery, and other *tours de force* of this kind, in burnt clay, from which we may draw wholesome lessons and precedents for transplantation to our own streets and squares.

If we go beyond the pure English style of brick design alluded to, we may distinguish these stages or manners in the employment of the material, two of which have already received considerable illustration in this country. There is the brick and stone style, the colored brick style, and the moulded brick style. The first, vulgarly known as brick with stone dressings, is indigenous, and in many cases is, in fact, merely the substitution of brick for stone in the unornamented parts of the structure, for the sake chiefly of economy; though it may be accompanied by a certain amount of "treatment" of the brick, by the introduction of lines or crosses of darker brick on the orthodox red brick ground. Though this is an imitation in brick and stone of a masonic style, rather than a distinct style, it has, nevertheless, a character of its own, and in old houses especially, where the conflicting brick and stone elements have been toned down by time, it is capable of very pleasing effect. But in more recent times this method of combining the two materials has been the medium for all kinds of architectural commonplaces and vulgarities. It affords a means of getting what is supposed to be an architectural effect at a reduced cost from that of stone, and is eminently useful in the production of the kind of dwellings or shops called "handsome" or "respectable," as the degree of stone embroidery is more or less profuse. It is especially disagreeable when carried out with those staring, cold-looking yellowish bricks, which are the bane of so much modern town architecture; and at the best, the system of combining brick and stone in this way produces patchwork, takes away entirely the homogeneous character of a building, and gives it a kind of put-together cabinet appearance, with what we have heard called the "architectural features" added and framed into the rest. It would be possible to use brick and stone together in a much more architectural way than this, making a basement of the one and superstructure of the other; for instance, instead of putting the stone in after a carpenter and joiner fashion, to make jambs and architraves to windows and doors. The colored brick architecture is, as far as this country is concerned, of modern origin, or rather importation. As carried out here, it is distinguished by great flatness of treatment, and a frequently violent opposition of strongly-colored patent brick; though lately there have been attempts to realize more delicate harmonies by the combination of stone of suitable tints. The style is, in fact, the importation here of a manner of architectural treatment arising not unnaturally in a southern climate, where there is plenty of light to bring out distinctions of tint, and where material of rich and delicate tints (marble) could be procured, either to be used alone, or to combine with and harmonize the more raw hues of brick and tile work. We have not the same facilities here. We have been smitten with "the brick and marble architecture" of Italy, and have transplanted it, minus the marble, into an atmosphere where we have only two things to choose between in the treatment of external color: either to make it very unpleasantly stray at first, or to see the effect obliterated by weather in a very short period. The colored brick style, when the buildings are new, gives certainly a variety to our town architecture, and does not there clash with the sense of association; but it quickly loses its effect. In this country, on the other hand, the style is an anomaly, not harmonizing with the color or with the sentiment of the landscape. The value to us of the introduction of this style is for interiors, where it can be treated more delicately without danger of losing its effect so soon; though even here it needs to be handled with a delicacy and refinement, in regard to choice and arrangement of tone, too often absent.

The genuine brick style, what we before called the moulded brick style, is that which has naturally and of necessity been developed in countries where the builders were obliged to trust to this as the only material available in any large quantities for realizing their designs. Like the timber style of Norway, the brick style of Pomerania and some other regions of northern Europe, is the genuine outgrowth of the necessities of the case. It is the attempt to do in brickwork what in other countries other Mediæval workmen accomplished in the grander and more plastic material, stone. And few things in the history of architecture are more interesting and more characteristic than the monuments left by builders contending with restricted materials, but determined to produce with these what effect they can. Like all styles formed in this natural and unaffected manner, the brick architecture of northern Europe is marked by a character at the same time distinct and homogeneous, and directly the result of the peculiarities of the material. Imitated in stone, the features of such a building as the Marien Kirche at Stralsund would appear for the most part anything but attractive; its unadorned spaces of wall would be bare and cold, its ornamental features thin, wiry, and starved looking. Recognize, however, the character and limitations of the material, and all this is changed, and the design comes out as a suitable effect and picturesque achievement. Nothing could more forcibly illustrate the relative nature of architectural design, and the extent to which the intellectual capacity, the reason, is appealed to by it, as well as the eye. It is noticeable, too, that the satisfactory effect fails where the material is strained to do what it cannot satisfactorily accomplish, as in the effort to build up long lines of mullion in such a material as moulded brick. Conversely, the long pilasters, the square turrets and pinnacles in the Pomeranian brick style, which in that style appear as a satisfactory and characteristic treatment, would, if carried out in stone, appear simply bald, the material being capable of so much more rich and free treatment.

Regarding this last as the true brick architectural style, in which the material is made use of to produce purely architectural effects of composition, surface ornament, and light and shade, through the means of moulding and arcading, but with its own peculiar manner suited to the exigencies of the material; the question then becomes, how far is it desirable, in a country where there is no lack of good average building stone, to carry out and enlarge upon a style which in reality expresses the absence of stone, and only came into existence on account of that absence? If anything like an imitation of the North German style were attempted, it would almost certainly be a failure; for it would be a deliberate putting of himself into fetters by the architect, who should be content to use an inferior and cumbrous material when he had better ready to his hand. Among our stone-yielding districts a building dependent entirely on brick is an anomaly. On the other hand, what we do learn from this brick architecture, among other things, is the value of homogeneous material and treatment, rather than patchwork of a better and a worse material. Brick architecture should be purely brick, architecturally speaking, and aim at brick effects and treatment, and not be dependent on extraneous stone features to make it pass for architecture. And where circumstances are such that it really will enable us to realize an architectural effect and feeling more economically than stone, as in neighborhoods where the stone of the district is poor or in small quantities, there will really be a valid reason for employing the artifical material; for there can be no doubt that as a mere material, in regard to tone and color, and even finish and durability in mouldings and ornaments, good brick is better than a soft and inferior stone. Such cases, however, are exceptional in this country; otherwise, a development of pure brick architecture here must be the result of a wish to obtain a new source of effect, something which our more usual ornamental building materials cannot realize. That this is possible with brick there is no doubt; but not economically; any brick building, to realize architectural effect of a high order, is likely to cost as much, or more, in time and workmanship, if not in material, as stone. Whether it is worth while to try experiments of this kind will depend entirely upon the way in which architecture is regarded. If we preserve the utilitarian theory, and regard a building as a necessary erection, to be set up of the most suitable and procurable materials, and with them made to look as picturesque as possible, brickwork can only retain its place in the very plain class of buildings it has hitherto chiefly been used for; anything beyond that will be best built of stone. If we regard architecture more as an ornamental art, in which we can take any material we like, and fashion it to suit our tastes, that is another thing, and it may be an interesting experiment; but the cases in which this view can be acted upon are not many; public architecture is for the most part indissolubly bound up with public economy, and experiments therein cannot be honestly or successfully made, to any but a very limited extent.

Where brickwork is to be used in architectural design, however, it must be observed that at present we are, in a second sense, in the position of "Israel in Egypt;" for "there is no straw given unto us,"—the material for the highest class of brickwork is not forthcoming; and even the need of a larger or a smaller brick than ordinary, for special purposes, requires something little short of an act of Parliament to produce the article.

Perhaps a little experimentalizing in brick design might at all events have the good effect of forcing our brick manufacturers a little out of their usual groove, and helping to demonstrate that there are more ways than one of using a material of this kind.

THE DRYING OF SEWAGE DEPOSITS.

From "The Building News."

The treatment of sewage may well be said to be one of the chief engineering questions of the day. We have this important subject forced upon us in countless different ways, and there can be but little doubt that, in another session or two at the utmost, Parliament will have to take the matter into consideration. The present state of what is well termed "the sewage question," can be very readily and briefly explained, and the more important difficulties the solution of it presents to us, enumerated. If we assume, as a starting-point, the necessity of water carriage, and make water the vehicle for the removal of fecal matters, we must purify this water, or remove from it, to a great extent, the substances by which it has been polluted, before discharging it into any stream or river. The recommendations of the Royal Commissioners appointed to inquire into the pollution of rivers, are absolute upon this point, and there can be no possibility of doubt that, in a few years at most, it will be illegal to discharge impure water into any river. A certain standard has been adopted by the Commissioners, and liquids transgressing this standard are deemed inadmissible into potable water. The attainment of the degree of purity set forth in this standard, in an economical way, will be the solution of the sewage question.

It is not necessary that we should here quote the regulations of the Commissioners; they have been drawn up after a most searching investigation into every possible mode of pollution, whether arising from the discharge of town sewage, or the far more dangerous polluting matters from our various manufactories. An investigation extending over seven years, and including the mineral pollution of Cornish mining streams, the cloth-works pollution of the Gloucestershire valleys; that resulting from the waste matters discharged from paper-mills, calico-mills, dye-works, and tanneries; the refuse from distilleries, cotton and woollen manufactories, and iron-works, and, in short, from every industry extant which gives rise to the production of liquid refuse. That water, however grossly it may have been polluted, may again be purified, has been repeatedly proved. Simple filtration through some six feet of soil, will, if the volume of water passing through the filters be carefully regulated, make the filthiest water clear, if not pure again; and this simple mode of dealing with sewage is at present the only one we know of which renders the effluent water pure enough to pass muster before the Rivers' Pollution Commissioners.

But filtration is not an economical mode of treating polluted waters; on the contrary, it is a most costly plan of solving the sewage question, and one that can never be undertaken by itself to deal with large volumes of sewage. If, however, instead of using our land as a simple filter-bed, we greatly extend the area of our operations, and make the surface into a farm, we shall at any rate get some return for our labor in the value of the produce we may be thus enabled to raise; and as, moreover, sewage water contains many valuable manurial ingredients, we may thus expect to get some additional profits from the materials we are dealing with. The land will, in fact, command a higher rent than it would for ordinary agricultural purposes. But for ordinary farming operations, we cannot arrange to have water flowing over and through the soil at all times of the year. For cereals, this would never answer; and in the winter, in time of frost, we could purify no water at all. Where it becomes necessary, therefore, to receive and treat large daily volumes of water throughout the year, sewage-farming is a failure commercially; though, where the quantity of water received is optional, and the rent is low, sewage-farming ought to be made to pay.

We have spoken above of the manurial value of sewage water; this value lies, of course, in its fecal ingredients. Of the valuable matters in sewage, those constituting one-eighth of the whole value are present in a state of suspension, and the remaining seven-eighths are in solution. Now matters in suspension, which constitute about one-half of the total impurity in sewage water, can readily be removed by precipitation; and sewage water so treated loses all, or nearly all, its apparent filthiness, and to the eye becomes bright and pure. If what appeared pleasant to the eye was the only test required for the admission of sewage into potable waters, those who hold to the various precipitation processes would have it all their own way. As we have, however, seen, little more than one-eighth of the total amount of polluting matters, or those having a manurial value, can be removed by this means. The remainder of the matters in suspension are harmless. Strange to say, with this fact staring them in the face, sewage-doctors have been bold enough to assert that not only could they make sewage-water quite pure by means of precipitation, but that out of the matters they thus obtained, they could prepare valuable manures; so valuable, indeed, as to pay the cost of treatment, and return a good margin of profit into the bargain. There are, in fact, enthusiasts still among us who believe in a profit thus accruing, and have risked their money to secure it. We have now to inquire into the materials used in precipitating sewage; we have only to point out that these are the tenets of one school of sewage-doctors, viz., that you may thus purify the sewage, and obtain out of it a profit by the sale of the so obtained manures.

We may point out here that for all methods of dealing with the water, by putting it over or through soil, a previous precipitation and defecation in tanks is a most valuable antecedent process, and was, indeed, insisted on in the case of the Birmingham Sewage Bill. Not only does less land suffice to deal with a given quantity of sewage under these conditions, but the clogging or choking of the pores by the suspended matter must be reduced to a minimum. Another plan, which had been put forward for the treatment of sewage, is the employment of filters composed of substances useful in themselves as manures, which, when they had done their work, might be sold with considerably increased value as manures. The fatal objection to this plan is the enormous area of the filtering bed required to disinfect the sewage of a populous town, and the great expense of the process. The only other precipitation plan is that advocated by General Scott, who employs the cheapest precipitants—lime and clay— and, disregarding entirely the manure question, burns the deposit into a cement.

In all processes for treating sewage by means of precipitation, the same difficulty crops up, viz., that of drying the sludge, and if we admit that, whether the liquid sewage is to be put on to land, or whether it is to be turned into a running stream at once, it must be previously defecated, we still find we are met by the same question: How can we cheaply and inoffensively dry the deposited sludge? We find in a contemporary, invitations to inventors to communicate their inventions bearing upon this point; and before attempting to solve the question, it may be as well to glance at what we know of its difficulties. The deposits resulting from a precipitation of sewage, whether by lime, sulphate of alumina, sulphate of iron, or phosphate of lime and alumina, which are among the chief materials which have been proposed for the purpose, differ but little as respects their powers of retaining moisture. There are already in several of our manufactures instances where substances have to be recovered in a dry state, after mixture with very large quantities of water. Thus in the manufacture of pottery or porcelain, and, in fact, of all the finer descriptions of clayware, the clays are first reduced to a very liquid mixture, and the water thus used has to be subsequently expelled. In the manufacture of Portland cement, the chalk and clay are incorporated in a wash-mill with large excess of water. In paper manufacture, the pulp, and, in artificial fuel manufacture, the peat, have each to undergo an admixture with enormous volumes of water. In starch manufacture, the starch has to be separated from the gluten in a very liquid mixture. In the manufacture of salt again from brine, and in some dozen processes we might enumerate, the difficulty of expelling a large proportion of water has to be met and grappled with, and all these processes have from time to time furnished by analogy suggestions more or less valuable to the manufacturer who has to deal with sewage sludge. The main difficulty in his case is the low value of the compound he has finally to obtain, the great tenacity with which the water is retained, and the complex nature of the materials he is dealing with. A gallon, or 70,000 grains, of average sewage contains, let us assume, for instance, 125 grains of impurities. On treating this sewage with 15 grains of lime (as the cheapest precipitant), we obtain a precipitation which, when it has settled, and the water has been expelled, will amount to 70 grains, or only one-thousandth part. The other half of the impurities being carried away in the effluent water.

We have, therefore, theoretically to deal with a thousand tons, or 224,000 gallons of such sewage in order to obtain one ton of dry solid extract. In practice the amount would be even larger, as we cannot retain in tanks the whole of the precipitate, and it cannot be entirely deprived of its water. Let us assume now, that, having treated a thousand tons of sewage with the requisite quantity of lime, the precipitate has been formed, and the mixture has been run into a tank; in an hour's time the sewage will become fairly clear, and the solid suspended matters will have sunk to the bottom. By means of a falling penstock, or some similar contrivances, ninety-nine hundredths of the water may be run off in a clarified state, leaving at the bottom a slimy mud, which will be found, on analysis, to consist of 90 parts of water, or, say 9 tons of water and one ton of solid matter. Now begins the real difficulty. How are we to get rid of this water quickly and cheaply? A clay manufacturer of the old school would say, build a slip kiln, *i. e.*, a long shallow evaporating pan, and drive off the moisture by means of hot flues. Well, this can be done; but we are dealing, not with clay, but with a substance much more retentive of moisture, and capable of giving off a highly unpleasant smell if the heat is not carefully managed. A Staffordshire manufacturer would recommend us to employ the clay presses, in favor of which he has entirely abandoned the use of slip kilns; but our sludge is frequently very corrosive, and destroys the cloths used to press it through. Moreover, we want, if we are making a manure, to drive off 75 per cent. of the water in the sludge, and the clay press will not, at any pressure we can safely employ, expel more than 40 to 50 per cent. We cannot send out the sludge in a semi-dry state. To shorten our description of the means that have been suggested for drying sludge, we may mention the centrifugal wringer, which would, it was supposed, drive off the water, and leave the suspended impurities in the machine. This plan of drying has, we think, many advantages, and requires more careful trial than it has hitherto received. The danger consists in the choking of the pores of the wringer by the semi-solidified sludge, which quickly forms cakes wholly impervious to water. Another plan proposed is the exhaustion of the air in cylinders covered with canvas, over which the sludge is caused to flow, and this plan has, we think, a fair chance of success. Messrs. Milburn have invented a stove consisting of a series of hot plates, upon which a thin layer of sludge is being constantly kept in motion. The only objection to this plan is that up to the present time the cost is very great per ton of the dried sludge; another and similar plan is a machine consisting of an iron cylinder surrounded by heated flues and in the centre of the cylinder the sludge is introduced. As the cylinder is caused slowly to rotate on its axis, the sludge flows and rolls over the heated interior surface, and is rapidly dried. This plan has many advantages, but it has not yet been made to work economically. What is really required is a machine capable of drying say 10 tons of sludge per diem, or bringing 10 tons of the liquid sludge, containing, as we have seen, 90 per cent. of moisture, down to a solid containing but from 10 to 15 per cent. of moisture—and none of the drying-machines we have yet seen can be said to have accomplished this. The cost of completely drying 10 tons of sludge, containing about 2,000 gallons of water, by means of an evaporating floor, ought not to exceed the price of a ton of coal in theory, but in practice the cost is considerably more. To obtain one ton of sludge, containing upwards of 50 per cent. of water, would seem to cost from 4s. to 7s. by the different processes we have examined. Having thus set forth what has been at present done towards the drying of sludge, we must leave the problem to our readers; it is one well worthy of consideration, and its speedy solution is of the utmost importance.

BOLLMAN TRUSS.

By W. ALLAN, McDonogh Institute, Md.

In the January number of Van Nostrand, the error into which Mr. Shreve has inadvertently fallen in calculating the chord strain in the Bollman truss is well set forth by Mr. T. H. Smith; and yet the heading of his article would seem to imply that the question as to the accuracy of his result, and the error of Mr. Shreve's, was still "open."

The method of calculating the chord strain in a Bollman, used by Vose and others and given by Mr. Smith, is the simplest and shortest; but it can be readily shown by using Shreve's method (that of moments), that his error lies in omitting from the equation the strains in the ties cut by the central plane. As Mr. Smith says, the strains in these ties do not neutralize each other; on the contrary, they combine.

Bisecting the loaded truss by a vertical plane, we cut 16 ties—eight of those coming from each end. For convenience, take the centre of moments at the foot of the central post. The two ties passing through this point will, of course, not appear in the equation of moments. Dropping perpendiculars from this centre upon each of the other intersected ties, and either calculating their length or measuring them on a scaled drawing, we find them to be in order (in the example given by Shreve and Smith).

1.657, 2.98, 4.07, 4.99, 5.75, 6.41. 7.00

Each of these perpendiculars applies to ten ties. The points in which these perpendiculars intersect the ties running from the left abutment, for instance, all lie on a circle described on the tie running to the middle post as a diameter.

The strains on the ties, met by the above perpendiculars, are in the same order—

39.92, 37.92, 34.69, 30.22, 24.53, 17.6, 9.42

Multiplying each form by its lever-arm, we have for the moments of the ties—

66.15, 113.00, 141.19, 150 82, 141.07, 112 82, 65.95.

Nor if W = entire load (240 tons) and L = entire length (160 ft.) and D = depth (15 ft.), and S = the unknown horizontal chord strain, the equation of moments taken about the foot of the central post when the truss is fully loaded is

$$\tfrac{1}{2}\,W.\,\tfrac{1}{2}\,L-\tfrac{1}{2}\,W.\,\tfrac{1}{4}\,L$$

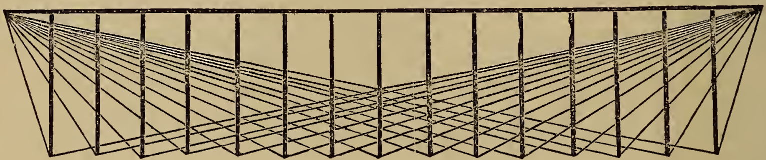
$$=S\ D-2\{66\ 15+113.+141.19+150.82+141.07+112.82+65.95\}=S.\ D-1582.$$

Substituting the values,

$$9600--4800=15.\ S-1582,$$

$$\therefore S=\frac{6382}{15}=425+$$

(The slight excess is due to the inexactness of the decimals.)



If I understand Mr. Smith's statement as to the constancy of "work done," when the "panel data" are the same, he seems to me in error. In a quadrangular truss of the dimensions and load of the Bollman above discussed, the "centre formula," as he calls it, or the formula for moments round a point in the centre of one of the chords when the truss is uniformly loaded, reduces to its simplest form and gives 320 tons for the chord strain in each chord, being tension in one and compression in the other. The chord strain is different, therefore, from that found for the Bollman and the Fink.

NOTES ON SEWAGE.

From "Engineering."

In a previous article we noticed the great difficulties which are presented to all schemes of sewage utilization by the albumenoid constituents of sewage, consequent on their slow decomposition. This fact has most especial reference to the chemical schemes that have been proposed, as it is the oxidation of such albumenoid substances which is an essential condition of success. Consequent on this, irrigation has a great advantage over any other method, for the prolonged action of the oxygen of the air eventually resolves such substances into fresh combinations, that thus become valuable as manure.

All the chemical schemes tend, owing to the employment of an acid sulphate of alumina, to solidify such albumenoids, and so render them less available for immediate use for manurial purposes. In the case of a rich specimen of the so-called Native Guano, it was found that after it was dried, several days elapsed during a daily summer temperature averaging 84 deg. Fahr. in the shade, before ammonia was evolved; while during autumn a similar class of manure might be kept for weeks before the resolution of such albumenoids into ammonia was effected. Hence the chemical analysis of liquids containing sewage contamination presents peculiar difficulties if such albumenoids of the class referred to are present in large quantities. The analysis of human urine gives a special illustration of this difficulty, and, perhaps, from this cause arises the paucity of the analysis of urine that now exists.

The amount of these albumenoidal substances present in a river into which sewage is emptied from adjacent towns, will, of course, depend on the number of the closets emptying themselves into the sewers, the population, the ratio of water supply, and some other causes which have been already noticed in the preceding articles. In some parts of the kingdom the use of water-closets is discouraged, as far as possible, by the local authorities, on account of a very uncertain and frequently short supply of water. Halifax is an instance of this kind. In such localities Goux's and other processes have been suggested, by means of which all the human excreta, including urine, but excluding waste water previously employed for washing, cooking, etc., are received in vessels containing an absorbent substance, and such vessels are periodically removed and replaced by others. Moule's earth system is admirably adapted for such purposes, and deserves application whereever such is admissible. The fact, however, cannot be concealed, that, at least in the South of England, local prejudices and domestic arrangements render its adoption all but impracticable, but some of its modifications might be followed.

It is remarkable that while a large portion of the North of England, a still larger proportion of the West of Scotland, and nearly one-seventh of the area of Ireland abound in peat, this substance has scarcely been used to be mixed with the excreta of our households. Of course here we do not refer to its natural state, but to the charcoal that may be obtained from it. Peat-charcoal is one of the most porous of all forms of impure carbon. Its powers of absorption, when dry, are very great. In experiments tried on the sewage of Leamington in 1870–71, it was found that two or three ounces of newly made peat-charcoal, obtained from near Bury, in Lancashire, were sufficient to deodorize six gallons of ordinary sewage. The actual proportions employed were about one part of charcoal to one hundred and fifty of sewage by weight. In a few minutes after the charcoal was mixed with the rich albumenoid sewage, a peculiar sweet smell was noticed; but in less than a quarter of an hour all smell had disappeared, and the constant addition of fecal matter did not permanently restore the smell. A closet arranged for the purpose was devoted to the use of 40 laborers, but even during the hot summer of 1870, on no occasion was any offensive smell noticeable, although the amount of peat-charcoal daily employed did not equal the proportion already stated.

We have already pointed out that continuously running sewage, having no hinderance in its progress to its outfall, rarely affords any gases that could be dangerous to health, but that wherever its continuous progress was delayed or stopped, these offensive and dangerous gases were evolved. In an article on "The Sanitary Retrospect of 1872" we have already discussed the effect of the excessive rainfall of that year as resulting in a decrease of mortality in the United Kingdom usually assigned to diseases of the zymotic class. We there suggested a variety of reasons why such a result should have occurred, and also pointed out certain lessons that might be deduced from the experience of November and December in 1872, and of January of the present year. There can be no doubt that the accidental circumstances of that period were highly favorable to public health, despite the fact that the average monthly temperature was about 10 deg. Fahr. beyond that of the preceding years. In fact, all or most of the substances which fall under the denomination of "previous sewage contamination," that is those albumenoid matters which we are now specially discussing, were driven off to the sea, in the majority of cases, in regard to our large towns, and under the general laws of physiological and chemical science, have been, or are now being returned to us in the form of various kinds of fish frequenting our coasts.

The difficulty under which we labor is to define the amount of excremental pollution which may at any time become dangerous in a running stream such as the Thames. It is highly probable in the latter case that a large proportion of the albumenoid or undecomposed nitrogenous matter of animal origin is not decomposed during its progress towards the sources whence some of the London water companies take their supply. Much has lately been said about the disfigurement which would arise near Hampton Court, if the Chelsea Water Works' proposition, to erect a reservoir, were carried into effect. We lately attended a most enthusiastic meeting in which that proposition was denounced as simply a question of the picturesque, but not one word was said in regard to the sanitary aspects of the question. We have before us the reports of two medical officers of health resident in two of our leading inland "Spas," but in neither of these is reference made to the combined question of sewage disposal, or the water supply, although in both cases the latter is contaminated by sewage.

An interesting paper on the determination of this organic nitrogen, by Mr. Wanklyn, appeared in the "Philosophical Magazine" of May, 1872, to which we must refer our scientific readers who wish to appreciate the difficulties we have named, so far as chemical analysis is concerned. Practically, we endeavored to overcome the difficulty by the following experiment; that is, we attempted to arrive at some method by which the nitrogenous matters could be eliminated from a sewage-contaminated river. A series of glass vessels were placed at successive elevations of a foot apart, in such a manner that the water (contaminated highly with sewage, and very offensive in smell) should fall drop by drop from the highest to the lowest, hence each drop passed through about 5 ft. in the open atmosphere. It required, however, to return the liquid four times to the upper vessel before the water became without odor or taste. In other words, besides accidental exposure to the atmosphere, while the liquid rested in each vessel, a fall of 20 ft. was needed, the entire surface of each drop being thus exposed to the oxidizing influence of the atmosphere.

This experiment still left much to be desired when its results were examined by careful chemical analysis. If with all the care that was bestowed on this attempt, resulting in no great benefit, what can be expected of the nature of river water, such as that of the Thames, contaminated with the sewage of scores of towns and villages, manured fields, etc, as a source of water supply for a large portion of the metropolis? Sewage fungus has long, and we believe, justly, been considered as a sign of dangerous conditions in a water supply. Dr. Frankland and many other authorities have endorsed this statement. It is somewhat remarkable that most fungoid growths have more or less inimical relations to human health. Hence, even the ordinary mushroom has frequently poisonous effect. Careful investigations in India during recent years have shown that certain fungoid growths on rice have been accompanied with outbreaks of diarrhœa and the severer forms of Asiatic cholera. The banks of the Thames and the Lea, and at times some parts of the New River, present instances of sewage fungus, especially during August and September. It is especially during these periods that diseases of the choleraic character are most prevalent, a result generally ascribed to the rotting of the weeds growing in such streams. But a little further examination will prove that the concomitant of such rotting is really the production of fungus. Even our trees are thus affected. A young and vigorous sapling never shows sign of fungous growth on its stem, while those of older growth are invariably tainted by it.

A careful chemical analysis of these fungoids discloses the presence of nitrogen; and this points to the fact that the albumenoid matters on which we are now treating may be considered as their source. Between Twickenham and Kew the Thames affords abundance of this growth, but as a rule it ceases beyond Erith to Gravesend, at which latter place sea-water produces new conditions of decomposition. Proceeding up the Thames beyond the limit of the tidal flow, the presence of sewage fungus is readily detected at all times when the river is not in flood, indicating the presence of sewage matter. In fact, for all practically sanitary purposes, the most cursory examination of the grass, etc., lining the banks and drooping into the stream, will be sufficient to indicate the presence of sewage fungus, and concomitantly the utter unfitness of such water for drinking purposes.

Dr. Frankland has justly stated that "sewage and animal excrementitious matters are believed sometimes to contain organic poisons, which when taken into the stomach are capable of producing in the human subject such diseases as cholera and typhoid fever, and yet that such poisons cannot be discovered by chemical analysis. Like the infecting matter of small-pox, cow-pox and glanders, and the venom of serpents, they can only be detected by their effects on animals, and more especially on man." It is not our business to discuss physiological or pathological questions, but still both the science and art of engineering must largely depend on the aid which such researches, combined with those of chemical science, afford. The engineer, architect, and ordinary builders are frequently presumed to be in fault, a special case of which was instanced in the case of the supposed causes of the dangerous illness of the Prince of Wales, and the death of Lord Chesterfield. But the real default in these as in perhaps thousands of similar cases, lay in the hands of medical and chemical authorities, rather than in those who had simply the supervision of the mechanical arrangements for the disposal of sewage.

The action of yeast on flour presents a very simple illustration of the effects of sewage fungus on the human system. Liebig pointed out some years ago an analogous action of the poisonous matter in German sausage, and possibly what is called *mussel-poisoning* may belong to the same category. To be practical, the engineer has no resource but that of using the best of his experience to get rid, as quick as possible, of the matters we have treated on in this article. Hitherto the profession has been almost neglected in this matter with respect to sanitary results; in fact they have been chiefly intrusted to patch up the defects of theories that have been applied at the suggestion of other professions. As Horace saith, if you can find a better plan we will adopt it; if not, we must still hold to our own. Perhaps our readers will pardon this free translation of a well-known remark made by that eminent Roman poet; it is apposite to our position.

SCIENCE AND PRACTICE IN TELEGRAPHIC ENGINEERING.*

Engineering may be defined as the application of practical science to man's material circumstances and means of action. As usual in classification, the nomenclature of branches of engineering is full of what the logician calls cross-divisions. Thus we have civil and military engineering, and again, civil and mechanical engineering; then architecture and building, engineering and contracting. We have, it is true, in the distinction between military and civil engineering a good logical division. Every subject of civil engineering is included in military engineering, because an army has all the wants of any large body of civilians. But military engineering includes more, because there is no civil purpose which requires rifled cannon, shot and shell, hand-grenades, torpedoes, iron-clads, armed fortications, mining under fire or under liability to hand-to-hand encounter with an enemy, and field telegraphs. I have enumerated all the subjects which I can think of that belong exclusively to military engineering, and, except these, all subjects of general engineering are embraced in civil engineering, properly so called. The division between military and civil engineering is, therefore, not properly founded on a distinction in respect to the subject matter, but it is a true logical division in respect to the province of application. Now remark the division between civil and mechanical engineering—a distinction habitually used, as if the engineering of merchant steamers, of cotton mills, of sugar machinery, of calico printing, of letter-press printing, were not truly parts of civil engineering. I make no complaint of the ordinary language which designates as civil engineering only that which is neither military, nor concerned with mechanism otherwise than in designing and testing it, and which calls mechanical engineering the construction, daily use, and maintenance of machines. I make no complaint of the ordinary language which so designates civil engineering, and distinguishes it from mechanical engineering. I only say that it is not logical. Take, again, architecture. Architecture is not commonly called a branch of engineering at all. I think it unfortunate that the public do not regard architecture as a branch of engineering. When architects come to regard themselves as engineers, and when the public come to expect them to act as engineers, let us hope they will give us buildings not less beautiful and not less interestingly connected with monuments and traditions of beauty from bygone ages than they give us now. But assuredly there will then be less typhoid fever. Then invalids too ill to walk, or ride, or drive out of doors, or to be benefited by the beautiful scenery of Mentono, or Corsica, or Madeira, will not be expatriated merely to avoid the evil effects of the indoor atmosphere of England. Then people in good health will not be stupefied by a few hours of an evening at home in gaslight, or of social reunion, or by one hour of a crowded popular lecture or meeting of a learned society. Then in our hotels, and dwelling-houses, and clubs, we shall escape the negatively refreshing influence of the all-pervading daily aerial telegraph, which prematurely transmits intelligence of distant and future dinners. The

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* Abstract from the address of Sir William Thompson before the Society of Telegraph Engineers.

problem of giving us within doors any prescribed degree of temperature, with air as fresh and pure as the atmosphere outside the house can supply, may be not an easy problem; but it is certainly a problem to be solved when architecture becomes a branch of scientific engineering. Now as to the relations between theory and practice in telegraphic engineering, I feel that I have more to say respecting the reflected benefits which electrical science gains from its practical applications in the electric telegraph, than of the value of theory in directing, and aiding, and interesting the operators in every department of the work of the electric telegraph. In no other branch of engineering, indeed, is high science more intelligently appreciated and ably applied than in the manufacture and the use of telegrapic lines, whether over land or under sea; and it would be quite superfluous for me to speak on that subject to those whom I see before me. But I do not know whether so much is thought of what the electric telegraph and its workers have already done, and may be expected yet to do, for science in general, and particularly electricity and magnetism. Time does not allow me to enlarge, as I would like to do, on this subject. I will merely remind those who are present of the great advance that has been made in accurate measurement within the last fifteen years. I need not tell you that a large part of the benefit thus achieved for science is due to the requirements of the practical telegraphist. Men of abstract science were satisfied to know that absolute measurement was possible, and that a definition of magnetic force, a definition of electric resistance, a definition of electromotive force, and so on through the list of numerical quantities in electricity, could each of them be defined in absolute measure. We owe to Gauss and Weber the first great practical realization in abstract science of a system of absolute measurement; but their principles did not extend rapidly even in the domains of abstract science where their theory was well understood, because the urgent need for its practical application was not felt. When accurate measurement in any definite unit first became prevalent was when it was required by the electric telegraph. The pioneers of science, many of whom, happily for us, still work for science and for the electric telegraph, laid down various perfectly definite units for the measurement of electric resistance—that most primary one of the various subjects for measurement. I need not remind any of you of the history of electric units of resistance, or of the labors of the Committee of the British Association to bring that system of measurement into harmony with the theoretical definitions of Gauss and Weber. The benefits conferred by introducing a system of definite measurement into the working of the electric telegraph are due not solely—perhaps not even in chief—to the application of Gauss's system, but to the introduction of very accurate and definite standards of resistance and means of reproducing those standards should the originals be lost. The benefit of putting the practical standards into relation with the science of Gauss and Weber has been set forth in the successive reports of the Committee of the British Association on electric measurement, and is well known, I believe, to most of the members of the Society of Telegraph Engineers. But now what I wish to say is, that theoretical science has gained great reflective benefit from the introduction of accurate measurement of resistance into practical telegraphy. For many years the measurements were performed in the office of the telegraph factory, and at the station-house of the telegraphic wire, the means of doing it, possibly—perhaps I might even say the principles on which those measurements were conducted — being still unknown throughout the scientific laboratories of Europe. The professors of science who threw out the general principle have gained a rich harvest for the seed which they sowed. They have now got back from the practical telegrapher accurate standards of measurement, and ready means of transmitting those standards and of preserving them for years and years without change, which have proved of the most extreme value to the work of the scientific laboratory. I might make similar remarks regarding electric instruments. The theory of electric instruments has been taught by those who have labored in theoretical science, but the zeal and ability with which the makers and users of instruments in the service of the electric telegraph have taken up the hints of science have given back to the scientific laboratory instruments of incalculable value. But I wish rather to confine myself to looking forward to the benefits which science may derive from its practical applications in telegraph engineering, and to point out that this Society is designed by its founders to be a channel through which these benefits may flow back to science, and, on the other hand, to supply the counter-channels by which pure science may exercise its perennially beneficial influence on practice. Time would fail me to give any such statement as would include a large part of the subject upon which I have touched; I shall therefore confine myself strictly to one point, and that is the science of terrestrial electricity. I have advisedly, not thoughtlessly, used the expression "terrestrial electricity." It is not an expression we are accustomed to. We are accustomed to "terrestrial magnetism;" we are accustomed to "atmospheric electricity." The electric telegraph forces us to combine our ideas with reference to terrestrial magnetism and atmospheric electricity. We must look upon the earth and the air as a whole—a globe of earth and air—and consider its electricity whether at rest or in motion. Then, as to terrestrial magnetism, what its relation may be to perceptible electric manifestations we at present know nothing. You all know that the earth acts as a great magnet. Dr. Gilbert, of Colchester, made that clear nearly 300 years ago; but how the earth acts as a great magnet—how it is a magnet, whether an electro-magnet in virtue of currents revolving round under the upper surface, or whether it is a magnet like a mass of steel or loadstone, we do not know. This we do know, that it is a variable magnet, and that a first approximation to the variation consists in a statement of motion round the axis of figure—motion of the magnetic poles, round the axis of figure, in a period of from 900 to 1000 years. The earth is not a uniformly magnetized magnet with two poles, and with circles of symmetry round those poles. But a first expression —as we should say in mathematical language, the first "harmonic term"—in the full expression of terrestrial magnetism is an expression of a regular and symmetrical distribution such as I have indicated. Now, this is quite certain, that the axis of this first term, so to speak, or this first approximation, which, in fact, we might call the magnetic axis of the earth, does revolve round the axis of figure. When the phenomena of terrestrial magnetism were first somewhat accurately observed about three hundred years ago, the needle pointed here in England a little to the east of north; a few years later it pointed due north; then, until about the year 1820, it went to the west of north; and now it has come back towards the north. The dip has experienced corresponding variations. The dip was first discovered by the instrument maker, Robert Norman, an illustration, I may mention in passing, of the benefits which abstract science derives from practical applications—one of the most important fundamental discoveries of magnetism brought back to theory by an instrument maker who made mariner's compasses. Robert Norman, in balancing his compass-cards, noticed that after they were electrified one end dipped, and he examined the phenomenon and supported a needle about the centre of gravity, magnetized it, and discovered the dip. Well, when the dip was first so discovered by Robert Norman it was less than it is now. The dip has gone on increasing, and is still increasing, although the diviation from true north is greatest. Everything goes on as if we had a pole which was distant from us on the far side of the pole of figure—what we commonly call the north pole—a magnetic pole first on the far side of the north pole. About three hundred years ago it was a little to the east of the north pole; then it came round, as we look at the north pole, eastward, and towards us, so as to describe a circle on the left-hand side of the pole, and back between us and the north pole towards the magnetic pole. That motion in a circle round the pole has already been experienced within the period during which accurate measurements have been made—has been experienced to the extent of rather more than a quarter of the pole revolution. It is one of the greatest mysteries of science, a mystery which I might almost say is to myself a subject of daily contemplation—what can be the cause of this magnetism in the interior of the earth? Rigid magnetization, like that of steel or the loadstone, has no quality in itself in virtue of which we can conceive it to migrate round in the magnetized bar. Electric currents afford the more favorable hypothesis; they are more mobile. If we can conceive electric currents at all, we may conceive them flitting about. But what sustains the electric currents? People sometimes say, heedlessly or ignorantly, that thermo-electricity does it. We have none of the elements of the problem of thermo-electricity in the state of underground temperature which could possibly explain, in accordance with any knowledge we have of thermo-electricity, how there could be sustained currents round the earth. And if there were currents round the earth, regulated by some cause so as to give them a definite direction at one time, we are as far as ever from explaining how the channel of those currents could experience that great secular variation which we know it does. Then we have merely a mystery. It would be rash to suggest even an explanation. I may say that one explanation has been suggested. It was suggested by the great astronomer, Halley, that there is a nucleus in the interior of the earth, and that the mystery is explained simply by a magnet not rigidly connected with the upper crust of the earth, but revolving round an axis differing from the axis of figure of the outer crust, and exhibiting a gradual precessional motion independent of the precessional motion of the outer rigid crust. I merely say that has been suggested. I do not ask you to judge of the probability: I would not ask myself to judge of the probability of it. No other explanation has been suggested. But now, I say, we look with hopefulness to the practical telegraphist for data towards a solution of this grand problem. The terrestrial magnetism is subject, as a whole, to the grand secular variation which I have indicated. But, besides that, there are annual variations and diurnal variations. Every day the needle varies from a few minutes on one side to a few minutes on the other side of its mean position, and at times there are much greater variations. What are called " magnetic storms " are of not very unfrequent occurrence. In a magnetic storm the needle will often fly twenty minutes, thirty minutes, a degree, or even as much as two or three degrees sometimes, from its proper position—if I may use that term—its proper position for the time; that is, the position which it might be expected to have at the time according to the statistics of previous observations. I speak of the needle in general. The ordinary observation of the horizontal needle shows these phenomena. So does observation on the dip of the needle. So does observation on the total intensity of the terrestrial magnetic force. The three elements, deflection, dip, and total intensity, all vary every day with the ordinary diurnal variation, and irregularly with the magnetic storm. The magnetic storm is always associated with a visible phenomenon, which we call, habitually, electrical. I mean aurora borealis, and I have no doubt, also, aurora of the southern polar regions. We have the strongest possible reasons for believing that aurora consists of electric currents, like the electric phenomena presented by currents of electricity through what are called vacuum tubes, through the space occupied by vacua of different qualities in the well known vacuum tubes. Of course, the very expression, " vacua of different qualities," is a contradiction in terms. It implies that there are small quantities of matter of different kinds left in those nearest approaches to a perfect vacuum which we can make. Well, now, it is known to you all that aurora borealis is properly comparable with the phenomena presented by vacuum tubes. The appearance of the light, the variations which it presents, and the magnetic accompaniments, are all confirmatory of this view, so that we may accept it as one of the truths of science. Well, now—and here is a point upon which, I think, the practical telegraphist not only can, but will, before long give to abstract science data for judging—is the deflection of the needle a direct effect of the auroral current, or are the auroral current and the deflection of the needle common results of another cause? With reference to this point, I must speak of underground currents. There again I have named a household word to everyone who has anything to do with the operation of working the electric telegraph, and not a very pleasing household word I must say. I am sure most practical telegraphers would rather never hear of earth currents again. Still we have got earth currents; let us make the best of them. They are always with us; let us see whether we cannot make something out of them since they have given us so much trouble. Now, if we could have simultaneous observations of the underground currents, of the three magnetic elements, and of the aurora, we should have a mass of evidence from which, I believe, without fail, we ought to be able to conclude an answer more or less definite to the question I have put. Are we to look, then, in the regions external to our atmosphere for the cause of the underground currents, or are we to look under the earth for some unknown cause affecting terrestrial magnetism, and giving rise to an induction of those currents? The direction of the effects, if we can only observe those directions, will help us most materially to judge as to what answer should be given. It is my desire to make a suggestion which may reach members of this Society, and associates in distant parts of the earth. I make it not merely to occupy a little time in an inaugural address, but with the most earnest desire and expectation that something may be done in the direction of my suggestion. I do not venture to say that something may come from my suggestion, because, perhaps, without any suggestion from me, the acute and intelligent operators whom our great submarine telegraph companies have spread far and wide over the earth, are fully alive to the importance of such observations as I am now speaking of. I would just briefly say that this kind of observation is what would be of value for the scientific problem—to observe the indication of an electrometer at each end of a telegraph line at any time, whether during a magnetic storm or not, and at any time of the night or day. If the line be worked with a condenser at each end, this observation can be made without in the slightest degree influencing, and therefore without in the slightest degree disturbing, the practical work throughout the line. Put on an electrometer in direct connection with the line, connect the outside of the electrometer with a proper earth connection, and it may be observed quite irrespectively of the signalling; when the signalling is done, as it very frequently is at submarine lines, with a condenser at each end. The scientific observation will be disturbed undoubtedly, and considerably disturbed by the sending of messages, but the disturbance is only transient, and in the very pause at the end of a word there will be a sufficiently near approach in the potential at the end of the wire connected with the electrometer to allow a careful observer to estimate with practical accuracy the indication that he would have were there no working of the line going on at the time. A magnetic storm of considerable intensity does not stop the working, does, indeed, scarcely interfere with the working of a submarine line, in many instances, when a condenser is used at each end. Thus, observations, even when the line is working, may be made during magnetic storms, and again, during hours when the line is not working, if there are any, and even the very busiest lines have occasional hours of rest. Perhaps, then, however, the operators have no time or zeal left, or, rather, I am sure they have always zeal, but I am not sure that there is always time left, and it may be impossible for them to bear the strain longer than their officials require them. But when there is an operator, or a superintendent, or a mechanic, or an extra operator, who may have a little time on his hands, then, I say, any single observation, or any series of observations that he can make on the electric potentials at one end of an insulated line will give valuable results. When arrangements can be made for simultaneous observations of the potentials by an electrometer at the two ends of the line, the results will be still more valuable. And, lastly, I may just say that when an electrometer is not available, a galvanometer of very large resistance may be employed. This will not in the slightest degree interfere with the practical working any more than would an electrometer, but it will be more difficult to get results of the scientific observations not overpoweringly disturbed by the practical working, if a galvanometer is used than when an electrometer is available. Still, where there is no electrometer, valuable results may be obtained by applying a galvanometer in the manner I have indicated. The more resistance that can be put in between the cable and the earth in circuit with a galvanometer the better, and the sensibility of the galvanometer will still be found perhaps more than necessary. Then, instead of reducing it by a shunt, let steel magnets giving a more powerful direction to the needle be applied for adjusting it. I should speak also of the subject of atmospheric electricity. The electric telegraph brings this phenomenon into connection with terrestrial magnetism with earth currents, and through them with aurora borealis, in a manner for which observations made before the time of the electric telegraph, or without the aid of the electric telegraph, have not given us any data whatever. Scientific observations on terrestrial magnetism, and on the aurora, and on atmospheric electricity, have shown a connection between the aurora and terrestrial magnetism in the shape of the disturbances that I have alluded to at the time of magnetic storms; but no connection between atmospheric electricity, thunderstorms, or generally the state of the weather—what is commonly called meteorology—has yet been discovered. There is just one common link connecting these phenomena and those exhibited in the electric telegraph. A telegraphic line—an air line more particularly, but a submarine line also—shows us unusully great disturbances not only when there are aurora and variations of terrestrial magnetism, but when the atmospheric electricity is in a disturbed state. That it should be so, electricians here present will readily understand. They will understand when they consider the change of electrification of the earth's surface which a lightning discharge necessarily produces. I fear I might occupy too much of your time, or else I would just like to say a word upon atmospheric electricity, and to call your attention to the quantitative relations which questions in connection with this subject bear to those of ordinary earth currents and the phenomena of terrestrial magnetism. In fair weather, the surface of the earth is always, in these countries at all events, found negatively electrified. Now the limitation to these countries that I have made, suggests a point for the practical telegraphists all over the world. Let us know whether it is only in England, France, and Italy that in fine weather the earth's surface is negatively electrified. The only case of exception on record to this statement is Professor Piazzi Smyth's observations on the Peak of Teneriffe. There, during several months of perfectly fair weather, the surface of the mountain was, if the electric test applied was correct, positively electrified; but Professor Piazzi Smyth has, I believe, pointed out that the observations must not be relied upon. The instrument, he found himself, was not satisfactory. The science of observing the atmospheric electricity was then so much in its infancy that, though he went prepared with the best instrument, and the only existing rules for using it, there was a fatal doubt as to whether the electricity was positive or negative after all. But the fact that there has been such a doubt is important. Now I suppose there will be a telegraph to Teneriffe before long, and then I hope and trust some of the operators will find time to climb the Peak. I am sure that, even without an electric object, they will go up the Peak. Now, they must go up the Peak with an electrometer in fine weather, and ascertain whether the earth is positively or negatively electrified. If they find that on one fine day it is negatively electrified, the result will be valuable to science; and if on several days it is found to be all day and all night negatively electrified, then there will be a very great accession to our knowledge regarding atmospheric electricity. When I say the surface of the earth is negatively electrified, I make a statement which I believe was due originally to Peltier.. The more common form of statement is that the air is positively electrified, but this form of statement is apt to be delusive. More than that, it is most delusive in many published treatises, both in books and encyclopædias, upon the subject. I have in my mind one encyclopædia, in which, in the article "Air, electricity of," it is said that the electricity of the air is positive, and increases in rising from the ground. In the same encyclopædia, in the article "Electricity, atmospheric," it is stated that the surface of the earth is negatively electrified, and that the air in contact with the earth, and for some height above the earth, is, in general, negatively electrified. I do not say too much, then, when I say that the statement that the air is positively electrified has been at all events a subject for ambiguous and contradictory propositions; in fact, what we know by direct observation is, that the surface of the earth is negatively electrified, and positive electrification of the air is merely inferential. Suppose, for a moment, that there were no electricity whatever in the air—that the air were absolutely devoid of all electric manifestation, and that a charge of electricity were given to the whole earth. For this no great amount would be necessary. Such amounts as you deal with in your great submarine cables would, if given to the earth as a whole, produce a very considerable electrification of its whole surface. You all know the comparison between the electricity of one Atlantic cable—the electro-static capacity of one of the Atlantic cables—with the water round its gutta-percha for outer coating, and the earth and air with infinite space for its outer coating. I do not remember the figures at this moment; in fact, I do not remember which is the greater. Well, now, if all space were non-conducting—and experiments on vacuum tubes seem rather to support the possibility of that being the correct view—if all space were non-conducting, our atmosphere being a non-conductor, and the rarer and rarer air above us being a non-conductor, and the so-called vacuous space, or the interplanetary space beyond that (which we cannot admit to be really vacuous) being a con-conductor also, then a charge could be given to the earth as a whole, if there were the other body to come and go away again, just as a charge could be given to a pith ball electrified in the air of this room. Then, I say, all the phenomena brought to light by atmospheric electrometers, which we observe on a fine day, would be observed just as they are. The ordinary observation of atmospheric electricity would give just the result that we obtain from it. The result that we obtain every day in observations on atmospheric electricity is precisely the same as if the earth were electrified negatively and the air had no electricity in it whatever.

Well, now, I have asserted strongly that the lower regions of the air are negatively electrified. On what foundation is this assertion made? Simply by observation. It is a matter of fact; it is not a matter of speculation. I find that when air is drawn into a room from the outside, on a fine day, it is negatively electrified. I believe the same phenomena will be observed in this city as in the old buildings of the University of Glasgow, in the middle of a very densely peopled and smoky part of Glasgow; and therefore I doubt not that when air is drawn into this room from the outside, and a water-dropping collector is placed in the centre of the room, or a few feet above the floor, and put in connection with a sufficiently delicate electrometer, it will indicate negative electrification. Take an electric machine; place a spirit-lamp on its prime conductor; turn the machine for a time; take an umbrella, and agitate the air with it till the whole is well mixed up; and keep turning the machine, with the spirit-lamp burning on its prime conductor. Then apply your electric test, and you find the air positively electrified. Again—Let two rooms, with a door and passage between them, be used for the experiment. First shut the door and open the window in your observing room. Then, whatever electric operations you may have been performing, after a short time you find indications of negative electrification of the air. Then, during all that time, let us suppose that an electric machine has been turned in the neighboring room, and a spirit-lamp burning on its prime conductor. Keep turning the electric machine in the neighboring room, with the spirit-lamp as before. Make no other difference but this — shut the window and open the door. I am supposing that there is a fire in your experimenting room. Then, when the window was open and the door closed, the fire drew its air from the window, and you got the air from without. Now shut the window and open the door into the next room, and gradually the electric manifestation changes. And here somebody may suggest that it is changed because of the opening of the door and the inductive effect from the passage. But I have anticipated that observation by saying that my observation has told me that the change takes place gradually. For a while after the door is opened and the window closed, the electrification of the air in your experimental chamber continues negative, but it gradually becomes zero, and a little later becomes positive. It remains positive as long as you keep turning the electric machine in the other room and the door is open. If you stop turning the electric machine, then, after a considerable time the manifestation changes once more to negative; or if you shut the door and open the window, the manifestation changes more rapidly to negative. It is, then, proved beyond all doubt that the electricity which comes in at the windows of an ordinary room in town is ordinarily negative in fair weather. It is not always negative, however. I have found it positive on some days. In broken weather, rainy weather, and so on, it is sometimes positive and sometimes negative. Now, hitherto there is no proof of positive electricity in the air at all in fine weather; but we have grounds for inferring that probably there is positive electricity in the upper regions of the air. To answer that question, the direct manner is to go up in a balloon; but that takes us beyond telegraphic regions, and therefore I must say nothing on that point. But I do say that superintendents and telegraph operators in various stations might sometimes make observations; and I do hope that the companies will so arrange their work, and provide such means for their spending their spare time, that each telegraph-station may be a sub-section of the Society of Telegraph Engineers, and may be able to have meetings, and make experiments, and put their forces together to endeavor to arrive at the truth. If telegraph operators would repeat such experiments in various parts of the world, they would give us most valuable information. And we may hope that besides definite information regarding atmospheric electricity, in which we are at present so very deficient, we shall also get towards that great mystery of nature—the explanation of terrestrial magnetism and its associated phenomena of the grand secular variation of magnetism, magnetic storms, and the aurora borealis.

And now, gentlemen, I must apologize to you for having trespassed so long upon your time. I have introduced a subject which, perhaps, more properly ought to have been brought forward as a communication at one of the ordinary meetings. I may just say, before sitting down, that I look forward with great hopefulness to the future of the Society of Telegraph Engineers. I look upon it as a Society for establishing harmony between theory and practice in electrical engineering—in electrical science generally. Of course, branches of engineering not purely electric are included, but the special subject of this Society is now, and I think must always be, electricity. Electric science hopes much from the observations of telegraphists, and particularly with the great means of observing that they have at their disposal. Science, I hope, will continue to confer benefits on the practical operator. This Society seems essential to make sure that the best that science can do shall be done for the practical operator, and that the work and observations of practical operators shall be brought together, through the channels of the various sub-sections, into one grand stream which this Society will be the means of utilizing.

ELECTRO-MAGNETS.

By COUNT DU MONCEL.

From "The Telegraphic Journal."

In my last note to the Academy of Sciences of Paris, I laid down a very simple formula, by which the diameter to be given to the core of a soft iron electro-magnet may be determined, that shall secure the best possible conditions in relation to the electro-motive force and resistance of a given circuit. This formula, which leads implicitly to the conclusion that, in the case where an electro-magnet is established under all maximum conditions, the diameter is independent of the resistance of the circuit, and proportional to the $\frac{2}{5}$ power of the electromotive force, only with relation to an electromotor, of which the wire is of the same diameter as that of the circuit. But this is not a general case, and it was desirable that the formula should extend to circuits composed of conductors different, whether in nature or in size. This part of the problem is that which I solve to-day.

We have seen that, in order to obtain the value c, that is to say, of the diameter of the iron of the electro-magnet, I took Muller's law, formulated by the equation

$$\frac{\mathrm{I}\,t}{\mathrm{I}'\,t'}=\frac{\sqrt{c^3}}{\sqrt{c'^3}}$$

c and c' representing the diameters of two electro-magnets, of which one, c', is the standard (*type de comparison*), which we suppose placed under convenient conditions; I and I′ are the current intensities; t t' the number of turns of spirals of the two helices.

We have seen further, that in order to obtain the values of t and t' in functions of known quantities, I have had recourse to the formulæ derived from the conditions of maximum of electro-magnets, with relation to their magnetizing bobbin, which give—

$$t=\frac{m\,c^2}{g^2},\mathrm{R}=\frac{2\,\pi\,c^3m}{g^2},\ \mathrm{I}=\frac{\mathrm{E}}{\frac{\mathrm{R}+\pi\,c^3\,m}{g^2}}$$

m representing the coefficient by which it is necessary to multiply the diameter c, in order to obtain the length of iron of the electro-magnet; g designating the diameter of the wire, covered with its insulating envelope; R, the resistance of the exterior, and E the total electro-motive force.* When the conductor of the exterior circuit is under the same conditions as the wire that constitutes the helix of the electro-magnet, R need not be reduced in function of g to furnish the value of t; but it is no longer the same if, the wire having an indeterminate diam-

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*"Comptes Rendus," vol. lxxxi., p. 1405.

eter, R is expressed in units of resistance other than that which serves to measure the length of the wire. It then becomes necessary to reduce R in function of g, for at least the evaluation of t. Now, as this reduction has for its expression $\frac{q\,R\,g^2}{f^2}$ (q representing a length equal to 375,000, when R is expressed in units of telegraph wire of 4 m. m. diameter, and f being the coefficient by which it is necessary to divide g, in order to obtain the wire deprived of its silk covering), we obtain for the value of t—

$$t = \frac{m\,c^2\sqrt{q\,R}}{\sqrt{f^2\,2\,\pi\,c^3\,m}} = \sqrt{c}\,\frac{\sqrt{R}}{f}\,\frac{m\sqrt{q}}{\sqrt{2\pi m}}.$$

The second part of the second member of this equation, being a constant, can be calculated with the known quantities resulting from the data furnished by the standard electro-magnet, and which are $\frac{\sqrt{c'^3}}{I'\,t'}$; so that we arrive at the simple expression—

$$c = \frac{E}{f\sqrt{R}}\left(\frac{m\sqrt{c'^3\,q}}{2\,I'\,t'\,\sqrt{2\,\pi\,m}}\right),$$

which may still be freed from the factor f, if we consider it as making for $I'\ t'$ that which it has made for $I\ t$, obtaining the equation—

$$c = c'\frac{E}{E'}\,\frac{\sqrt{R'}}{\sqrt{R}}\,\frac{f'}{f}.$$

But the quantity between parentheses of the second member of the preceding equation may be easily calculated; and according to the conditions of the standard electro-magnet I have employed, it is equal to 0.0000288 when f does not figure in the formula, or to 0.00004394 when that quantity is there represented, which is unnecessary, since the ratio $\frac{f'}{f}$ is sensibly equal to I.

There result from this formula several important consequences, which may be rendered thus :—

1. For circuits of equal resistance, the diameters of an electro-magnet should be proportional to the electro-motive forces.

2. For equal electro-motive forces, these diameters should be in inverse ratio to the square root of the resistance of the exterior circuit, comprising the resistance of the battery.

3. The value of these diameters (supposing that the resistance R of the exterior circuit be expressed in metrical units of telegraph wire of 4 m.m. diameter, and that the value of E be calculated upon the hypothesis that the electro-motive force of a Daniell element is represented by 5973) has for its expression—

$$c = \frac{E}{\sqrt{R}}\,0.0000288\ \ .\ \ .\ \ \text{metres.}$$

and the figures obtained represent a fraction of a metre.

4. In employing for the value of E the ratio of the given electro-motive force to that of a Daniell element taken as unit, the formula becomes—

$$c = \frac{E}{\sqrt{R}}\,0.172175\ \ .\ \ .\ \ \text{metres.}$$

and the value of R be always expressed in metric units of telegraph wire.

5. In reducing the values of E and R to the co-ordinate system of electric measures of the British Association, that is to say, to the *volt* or unit of electro-motive force which represents $\frac{9}{10}$ of the force of a Daniell element, and to the *ohm*, which is equivalent to 100 metres of telegraph wire of 4 m.m. diameter, the formula becomes—

$$c = \frac{E}{\sqrt{R}}\,0.01957\ \ .\ \ .\ \ \text{metres.}$$

or, in estimating the diameter in *mils*, the English measure representing thousandths of an inch,

$$c = \frac{E}{\sqrt{R}}\,628.223\ \text{mils.}$$

According to these formulæ, we can calculate that the diameter of an electro-magnet worked by a Bunsen element (medium size) on a circuit having no other resistance than that of the electro-magnet, should be—

$$c = \frac{1.86}{\sqrt{57}}\,0.172175 = 0.0424^{m.};\ \text{or}$$

1 in. 674 mils.

Again an electro-magnet interposed in a circuit of 118,620 metres, and worked by a Daniell battery of 20 elements, should have a diameter represented by—

$$c = \frac{20}{\sqrt{118620}}\,0.172175 = 0.01^{m.}$$

or taking English units,

$$c = \frac{\overset{\text{Volts.}}{21\ 58}}{\sqrt{1186.2}}\,0.015957 = 0.01^{m.} = 393{:}7\ \text{mils.}$$

The diameter *c* obtained, the total length of the two bobbins of the electro-magnet become, for the first, 51 centimetres, or $25\frac{1}{2}$ centimetres for each of the branches; and, for the second, 12 centimetres, or 6 centimetres for each bobbin.

The size of the wire can, as I have already said, be deduced from the following equations, when *c* is determined.*

$$g=\sqrt{f\sqrt{\frac{c^2}{R}0.00002106}}\text{ metres,}$$

which gives, for the first electro-magnet, $g=0.04865m.$, comprising the insulating covering, and $0.00336m.$, without this covering. The length of the wire is, with this diameter, $242.8m.$, and this quantity, reduced in telegraph wire (by dividing by 6 and by multiplying by the ratio of the sections), gives 57 metres as the value of R. For the second electro-magnet, these values are $g=0.0002597$ with the insulating covering, and 0.0001583 without the covering, with a length of wire of $1116.7m.$

The attractive force of these two electro-magnets with distance of the armature of 1 m.m., and taking the force of the standard electro-magnet, which is 25 grammes for a circuit of 1186.20 metres, is, for the first, 23.112 kilograms, and for the second, 26.85 grms.; this at least is the force which results from the laws of Dub and Müller, represented by the formula—

$$\frac{F}{F'}=\frac{I^2\,t^2\,c^{\frac{3}{2}}}{I'^2\,t'^2\,c'^{\frac{3}{2}}}.$$

These several formulæ show why the electro-magnets interposed on long circuits should be of small dimensions, wound with fine wire; and why, on the contrary, they should be large when the circuit is short.

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* The coefficient of this formula is a little lower than that I have given (vol. lxxvii., p 351, of "Comptes Rendus.") This is owing to my expressing the ratio of the conductivities of iron and copper higher than it is practically, and that the diameter of the iron was below its true value.

DYNAMITE EXPERIMENTS.

From "London Mining Journal."

Some exceedingly interesting experiments with Dynamite, as a blasting agent, were recently conducted at Bardon Hill Granite Quarry, near Leicester. The Bardon Hill Quarry is one of the largest and oldest in the neighborhood, and is noted for the extreme hardness of its stone. The first truck load of stone for road-making sent into London by rail was sent from this noted quarry. The stone which is being got out, according to an analysis made some three years ago, by Kirkcaldy, proves this granite to be the hardest in the country, which the following table will show:—

	Pressure on 1 sq. in. Crushed at lbs.	Pressure on 1 sq. ft. Crushed at tons.
Bardon Hill Quarry	20,742	1334
Mansfield "	19,096	1228
Mount Sorrel "	17,533	1128
Grimsby "	15,062	970

By the above it is clearly shown that of the four quarries Bardon Hill granite is by far the hardest, and it frequently happens that in this quarry 50 lbs. weight of powder is used at a blast, and on one occasion as much as 500 lbs. of powder was used at a charge. The stone got from this quarry is crushed by machinery into different sizes, and is much sought after for road and drive making, from the fact of its being so tough; it is also used for building purposes.

Mr. Thomas Johnson, of the firm of Johnson and Co., Trindle-road, Dudley, attended to conduct the experiments. As there was a good programme to go through, the proceedings commenced early. Messrs. Ellis and Everard desired to see for the first experiment some large loose pieces of granite broken. These were detached from the solid and lying at the bottom of the quarry, some of them weighing as much as 6 or 8 tons each. It is usual in breaking these blocks of stone by blasting-powder to churn a hole in 10 to 12 in. deep, and it often occurs in doing so the workman, in consequence of the excessive hard nature of the granite, loses the points of half-a-dozen steel tools in doing so. There were some seven or eight of these monster blocks of granite to practise upon with dynamite, and a hole was churned in each piece sufficiently deep enough to cover the cartridge, which were some of the smaller ones, $3\frac{1}{4}$ in. long by $1\frac{1}{4}$ in. in diameter. A single dynamite cartridge, primed with cap and fuse, was inserted into one of the largest of these blocks, a little clay being placed over it, so as to tack it to its place; the shot was fired, and when the visitors returned to the spot they were agreeably surprised at the execution done by one single cartridge, the piece of granite being shivered into fragments.

The next experiment was by breaking two of the pieces of granite by firing them together, to show how time may be saved by breaking the two at once. Consequently two of the largest pieces were selected by the party, and charged with one small cartridge each, a little clay being put over them. Both charges were fired, and there was only a quarter of a minute between the two reports, and on the party returning it was found that both pieces were broken to atoms, and tumbled in all directions.

The next experiment was what is usually known in the quarry as a heaving shot—a solid mass of stone lying at the bottom of the quarry that required blowing, or, in other words, heaven up, before other stone can be comfortably worked. In this solid mass a hole was drilled 1½ in. in diameter and 20 in. deep; a 1¼ in. cartridge was gently rammed home with a wooden rammer. The hole was then filled up with water, which seemed to surprise the visitors. The charge was fired, and the whole mass lifted up so that it could be conveniently loaded without the use of the sledge. Mr. Everard, one of the firm, said he felt highly pleased with this experiment, as he considered this the most difficult of all the experiments that had been tried.

The next experiment was a breast shot in the solid. A hole was bored in the granite some 12 ft. up the face, 4 ft. deep, and 2½ in. in diameter. As this hole was by mistake put in 2½ in. diameter instead of 1½ in., and would not fit the 1¼ in. cartridges, Mr. Johnson loaded the hole with the loose dynamite out of six cartridges; the hole was then rammed up with sand, the charge was fired, and the whole layer of granite dropped; one of the visitors saying he should judge that there were 80 tons brought down by this shot. The next experiment was by throwing a cartridge against the rugged sides of the quarry, to show that dynamite will not explode by concussion; the cartridge simply struck, bursted itself, and dropped like so much loose sand. The next, and last, experiment was throwing cartridges into a blazing fire, which had been made in the quarry, to show that fire will not explode it, the consequence being that the dynamite mouldered away like so much cork burning. Of many experiments with Explosives at this quarry none have proved so satisfactory as those with dynamite.

ON THE CHOICE OF STEAM-ENGINES AND BOILERS.*

From "English Mechanic and World of Science."

It is estimated that 75 per cent. of the whole quantity of coal raised in Britain is absorbed in our various manufacturing industries, and the total quantity increases yearly. By far the greater proportion of this is no doubt consumed in the manufacture of iron, but the quantity of coal devoted to the production of motive power in the iron and other industries is very considerable. In the good old days of cheap coal, cheap labor, and easy competition, economy of manufacture was but little studied. Now, however, in many manufactures the most rigid economy has to be practised, if profits are to be made. And with coal at its present price, manufacturers scarcely need to be reminded that a low-priced wasteful steam-engine means a serious diminution of the yearly profits.

Economical steam power is, however, a compound result made up of many factors, of which safety is of first importance, since it is evident that a single explosion may in a moment cause a loss of life and property infinitely greater in value than the result of many years' economical working. Freedom from break-downs is also highly necessary to economical steam power, as it is easily conceivable that the inconvenience and loss arising from the stoppage of work consequent on a break-down of the engine, would in many cases outweigh any gain arising from economy of fuel merely. The cost of the engine itself, and the cost of its repairs, is another necessary consideration, because it is quite possible to buy economy of fuel at too high a price. If, for instance,

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*Extract from a pamphlet entitled "Useful Information on Steam Power," by Henry Northcott.

the interest on the extra cost of the so called economical engine, with its yearly extra cost of repairs, exceeds the value of the fuel saved, the manufacturer is evidently paying more than twenty shillings for a sovereign. That a steam-engine may be safe, durable, and economical of fuel, there need be no manner of doubt; but some little care and discrimination are required in the choice of an engine that shall combine these good qualities.

Careful experiments by Favre, Silbermann, and others, have shown that a pound of good coal will liberate during complete combustion 14,000 or 15,000 units of heat, each unit being equivalent to 772 foot-pounds. The mechanical equivalent of the heat developed by the combustion of a pound of coal is, therefore, say $14,500 \times 772 =$ over 11,000,000 foot-pounds. A horse-power is always assumed to be equal to 33,000 foot-pounds per minute, or 1,980,000 foot-pounds per hour. So that the combustion of each pound of coal per hour liberates heat enough to develop $11,000,000 \div 1,980,000 =$ say, 5 horse-power; and in a perfect steam-engine the consumption of coal would be about at the rate of one-fifth of a pound per hour for each horse-power developed.

The greatest economy obtained in ordinary continuous working may be taken at from 3 to 4 lbs. of coal per indicated horse-power, with non-condensing engines and from 2 to $2\frac{1}{2}$ lbs. with condensing engines. A consumption as little as $1\frac{1}{4}$ or $1\frac{1}{2}$ lb. per indicated horse-power has been reported in the case of compound condensing engines, and such results are quite possible. But a consumption of 2 lbs. is as little as can yet be counted on with certainty. The manufacturer, in choosing an engine, would do well to look with some little doubt on promises of a better result than this, and he may feel satisfied if the engine he buys shows itself capable of working with that degree of economy. A consumption of 4 lbs. of coal per indicated horse-power per hour, means a loss of nineteen-twentieths; and of 2 lbs. per indicated horse-power, a loss of nine-tenths of the power theoretically due to the coal. There is, therefore, ample room for improvement, even upon the best of modern steam-engines.

The conditions necessary to economy in the steam-engine are, 1st: The complete combustion of the fuel in the furnace. 2d. The transfer of all the heat generated to the water in the boiler. 3d. The passage of the steam through the engine without loss of heat, except such as is converted into motive power, and the conservation of the heat remaining in the steam on its leaving the cylinder. 4th. The absence of friction in the working of the engine. Let us see how these conditions are fulfilled in a good modern steam-engine.

As to the combustion of the fuel, with the best coal and most careful stoking, a quantity of the coal falls through the fire-bars, either as unburnt coal or as ashes. Another portion goes up the chimney unconsumed in the form of smoke and soot; and a further quantity half consumed in the form of carbonic oxide. The loss from these causes may amount to from 2 to 20 per cent. It all arises from wrongly constructed furnaces and bad stoking, and it may nearly all be avoided.

As to the heat generated,—most coal contains a greater or less quantity of moisture, and the evaporation of this moisture causes the first loss of heat. Radiation from the furnace causes a further loss. But the great causes of loss are the admission into the furnace of a large quantity of useless air and inert gases, and the escape of these with the actual products of combustion, up the chimney, at a very much higher temperature than that at which they entered the furnace. Air is composed of about one-third oxygen and two-thirds nitrogen. The oxygen only is required to effect the combustion of the fuel, and the useless nitrogen merely abstracts heat from the combustibles, and lowers the temperature of the furnace. About 12 lbs. of air contain sufficient oxygen to effect the combustion of 1 lb. of coal, but owing to the difficulty of bringing the carbon into contact with the oxygen, the quantity actually required to pass through the furnace is from 18 lbs. to 24 lbs. of air per pound of coal burnt. The surplus air passes out unburnt, but its presence in the furnace lowers the temperature subsisting there, and abstracts a portion of the heat generated. And whereas the whole of the air enters the furnace at about 60 deg. Fahr., the unconsumed air and the products of combustion leave the flues at from 400 deg. Fahr. to 800 deg. Fahr. The total loss from these causes is from 20 to 50 per cent. In other words, whereas each pound of good coal burnt is theoretically capable of evaporating about 15 lbs. of water in good practice it evaporates but 9 or 10 lbs., and in ordinary practice but 6 or 8 lbs. of water.

There are difficulties in the way of abstracting all the heat from the furnace gases: firstly, because with natural or chimney draught, the gases require to pass into the chimney at not less than 500 deg. Fahr., in order to maintain the draught; and secondly, because the transmission of heat from the gases to the water, when the difference of their temperatures is small, is so slow, that an enormous extension of the surface in contact with them becomes necessary in order to effect it. But by having energetic combustion and a high temperature in the furnace, the quantity of air actually required may be much reduced; by suitable arrangements for admitting air and feeding the coal into the furnace, the proportions of each may be suitably adjusted to each other; and by a liberal allowance of properly-disposed heating surface, the temperature of the reduced quantity of furnace gases may be reduced to that simply necessary to produce a draught, in a furnace with natural draught, or to about 400 deg. Fahr. or less, in a furnace where the draught is obtained from a steam-jet or fan. Under these conditions an evaporation of from 10 to 12 or more pounds of water per pound of good coal burnt, may be expected.

As to the heat in the steam,—amongst the minor causes of loss are, radiation from the boiler, steampipes, and engine (most of which can be prevented by careful lagging with a good non-conductor of heat); blowing-off, and leakage. A greater loss arises from initial condensation in unjacketed cylinders, nearly prevented by using a properly-constructed steam-jacket. But the great loss arises from the escape of the steam into the atmosphere, with only a portion of its heat utilized. This, of itself, leads to another great loss of from 40 to 60 per cent.

The use of high-pressure steam, high rates of expansion, and of an efficient feed-water heater, is conducive to economy, but no practicable means have yet been devised whereby the whole heat may be saved; and the removal of this source of loss in the working of the steam engine offers one of the most promising subjects for inventive genius.

In a good modern steam-engine the coal used is thus approximately disposed of:—

Lost through bad stoking and incomplete combustion	10.0
Carried off in the chimney gases	30.0
Carried away in the exhaust steam	50.0
Utilized in motive power (indicated)	10.0
	100.0

Engine Friction.—A further loss of useful effect ensues from a portion of the motive power actually developed being absorbed in driving the engine itself, and the useful power of the engine is reduced from this cause by from 5 to 25 per cent. The use of equilibrium valves, ample bearing surfaces, careful lubrication, and cleanliness, go far to lessen the friction, as well as to increase the working life of a steam-engine; but in selecting an engine it is as well to bear in mind this source of loss, as injudicious improvements, introduced for the attainment of increased economy, may defeat this object through the excessive power required to drive them.

For engines with cylinders less than 6 or 8 in. diameter, the simple high pressure non-condensing arrangement should be adhered to, as it makes for small powers the most economical as well as the cheapest engine. The boilers for the smaller powers can be heated by gas instead of by coal, and the cleanliness and convenience of the arrangement quite counterbalance the slight increase of expense. When also the trouble of attending often to the water-level is objected to, a boiler of large capacity should be provided. Non-condensing engines with cylinders above 8 in. diam. should always be provided with expansion valves, steam-jacketed cylinders, and feed-water heaters; and the exhaust steam of non-condensing engines should always be used to urge the draught. Condensers cannot well be used for portable engines or engines requiring removal; but fixed engines, having cylinders larger than about 10 or 12 in., should be fitted with either surface or jet condensers. The jet condenser is less costly and nearly as efficient as the surface condenser, under ordinary circumstances; but when the water from which steam is made contains much impurity, surface condensation is to be preferred. For seagoing purposes engines are now very generally made on the compound system, and some very good results have been obtained from such engines. Their use for land purposes also is becoming very general, and for large powers the compound engine is to be recommended. But it should be borne in mind, that whereas a compound engine must be both designed and constructed with the greatest skill and care, in order that it may work with greater economy than a good ordinary engine, a bad compound engine may easily be much more wasteful than even a bad ordinary engine.

The unmistakable tendency of modern steam-engineering is towards much higher pressures of steam than those hitherto used. A pressure of over 100 lbs. per inch means the supercession of what may be termed large-capacity boilers. High-pressures are as safe as low-pressures, provided the boilers are suitably designed to withstand them. But the construction of high-pressure boilers should be confided to none but competent engineers; and those who intend putting up new boilers should recollect that the boiler-maker who uses the best quality plates and workmanship is not likely to send in the lowest tender. His boiler may, nevertheless, be the cheapest. For land purposes and moderate pressures the Cornish boiler will continue to be used. For higher pressures a modification of the French or elephant boiler is better, and the multitubular boiler is also to be preferred. The enormously thick plates found necessary in some modern marine boilers lead to most serious inconvenience, and it becomes essential to stipulate that steam shall not be got up in less than several hours. Many attempts have been made to use tubulous boilers for very high pressures, but as yet without any marked success. A good boiler of the kind, however, is a great desideratum.

The actual, or useful, or dynamometrical horse-power, is the net power of the engine, after allowing for friction, etc., and this alone is the power with which users of steam-engines are concerned. In small engines the useful power can be ascertained accurately by the application of a friction brake or dynamometer. The dynamometer, however, cannot be conveniently applied to large engines, but the indicated power, less an allowance for friction, gives the actual power near enough for most practical purposes.

In comparing the prices of different engine-makers, it is very necessary to look at the actual power an engine exerts, and not to the nominal power, or to the size alone of the cylinder. A nominal horse-power means anything from 1 to 8 actual horse-power, and of two engines of the same size and general construction, one may not only develop much more power than the other, but may do so with a less consumption of fuel per actual horse-power.

Coal varies so much in quality that the consumption of a certain weight per horse-power is not in itself sufficient to show the economy with which an engine works. When an engine consumes so little as 2 lbs. of coal per horse-power, we know that the coal used must be of good quality, and that the engine is an economical one. But the consumption of three or four times that weight of coal per horse-power does not necessarily prove the engine to be a bad one, because the coal used may be but one-third or one-fourth as good. Generally, no doubt the best coal is also the cheapest; but when an inferior quality is used, and it is desired to test the efficiency of a steam-engine, an analysis by a competent chemist will show the relative heating value of the fuel, compared with that of standard quality. The best steam-coal is capable of generating sufficient heat to evaporate about fifteen pounds of water from and at 212 deg. Fahr. per pound properly burnt. The same coal after a long sea-voyage or long exposure to weather often loses much of its calorific power, owing to its partial decomposition, pulverization, absorption of moisture, and other causes. Other kinds of coal contain a large percentage of incombustible matter, and knowing its chemical composition will alone enable one to judge of its comparative theoretical efficiency. Anthracite coals give the best results in generating steam, but bituminous coals may be burnt with a high degree of efficiency under suitable arrangements.

Stoking.—After the engineer has done all he can to attain economy, much of the result remains in the hands of the steam-user. A reduction of $\frac{1}{4}$ lb. of coal per indicated horse-power under 2 lbs., can only at present be effected by the greatest skill on the part of the engineer, whilst a careless or unskilful stoker may easily counteract all the engineer's ingenuity. The use of a high-class steam-engine involves the necessity of employing an intelligent, careful attendant. Not that the work is more difficult, at any rate, with good coal, nor is it so laborious, as less coal has to be thrown into the furnace for a given power. The impracticable style of stoking encouraged by the Royal Agricultural Society certainly involves the most watchful attention and unceasing labor, and if this were good stoking, carelessness would be excusable. Clean fire-bars, an evenly-spread grate, preliminary coking on the dead plate, and the exercise of some little intelligence in the admission of air and regulation of the draught, are the main points to be attended to by the stoker, and these cannot be said to involve an unreasonable amount either of labor or vigilance. A self-feeding grate is conducive to economy, especially when the coal is small or of inferior quality. Its use lessens the stoker's labor considerably, and it is not easy to find a reason for its comparatively limited adoption.

THE CHANNEL TUNNEL.

From "The Architect."

At a meeting of the Institution of Civil Engineers recently, Mr. Joseph Prestwich read a paper on "The Geological Conditions affecting the Construction of a Tunnel between England and France."

Taking the several formations in their order of superposition, Mr. Prestwich considers that a trough of London clay from 300 ft. to 400 ft., or more, in thickness, extends from the coast of Essex to the coast of France, and, judging from the experience gained in the Tower Subway, and the known impermeability and homogeneity of this formation, he thinks there is no difficulty, from a merely geological point of view, in the construction of a tunnel, but for the extreme distance—the nearest suitable points being 80 miles apart. The Lower Tertiary strata, which came next, were too unimportant and too permeable for tunnel work. The Chalk in this area was from 400 ft. to 1,000 ft. thick; the upper beds were soft and permeable, but the lower beds were so argillaceous and compact as to be comparably impermeable. In fact, in the Hainaut coal fields they effectually shut out the water of the water-bearing Tertiary strata from the underlying Coal Measures. Still, even the Lower Chalk is not suited for tunnel work, owing to its liability to fissures, imperfect impermeability, and exposure in the Channel. The Gault is homogeneous and impermeable, but near Folkestone it is only 130 ft. thick, reduced to 40 ft. at Wissant, so that a tunnel would hardly be feasible. The lower Greensands, 260 ft. thick at Sandgate, thinned off to 50 ft. or 60 ft. at Wissant, and are all far too permeable for any tunnel work. Again, the Wealden strata, 1,200 ft. thick, in Kent, were reduced to a few unimportant rubbly beds in the Boulonnais. To the Portland beds the same objections existed as to the Lower Greensands—both were water-bearing strata. The Kimmeridge clay is 360 ft. thick near Boulogne, and no doubt passes under the Channel, but in Kent it is covered by so great a thickness of Wealden strata as to be almost inaccessible; at the same time it contains subordinate water-bearing beds. Mr. Prestwich is, however, of opinion that, in case of the not improbable denudation of the Portland beds, it might be questionable to carry a tunnel in by the Kimmeridge clav on the French coast, and out by the Wealden beds on the English coast. The Oolitic series presented conditions still less favorable, and the lower beds had been found to be water-bearing in a deep artesian well recently sunk near Boulogne. The experimental deep boring now in progress near Battle would throw much light on this part of the question.

The Palœozoic series, which are next met with, consist of hard Silurian slates, Devonian and carboniferous limestones and coal measures having a probable thickness together of from 12,000 to 15,000 ft. These pass under the chalk in the north of France, crop out in the Boulonnais, are again lost under newer formations near to the coast, and do not reappear until in the neighborhood of Frome and Wells. But, although not exposed on the surface, they have been encountered at a depth of 1,032 ft. at Calais, 985 ft. at Ostend, 1,026 ft. at Harwich, and 1,114 ft. in London. They thus seem to form a subterranean table land of old rocks, covered immediately by the chalk and Tertiary strata. It was only as the southern flank of this old ridge that the Jurassic and Wealden series set in, and beneath these the Palœozoic rock rapidly descended to great depths. Near Boulogne these strata are already 1,000 ft. thick; and at Hythe, Mr. Prestwich estimates that their thickness might be that or more. Supposing the strike of the coal measures and the other Palœozoic rocks to be prolonged from their exposed area in the Boulonnais across the Channel, they would pass under the Cretaceous strata somewhere in the neighborhood of Folkstone, at a depth estimated at about 300 ft., and near Dover at about 600 ft., or nearly at the depth at which they had been found under the chalk at Guines, near Calais, where they were 665 ft. deep. These Palœozoic strata were tilted at high angles, and on the original elevated area they were covered by horizontal Cretaceous strata, the basement beds of which had filled up the interstices of the older rocks, as though with a liquid grouting. The overlying mass of gault and lower chalk also formed a barrier to the passage of water so effectual, that the coal measures were worked without difficulty under the very permeable tertiary and upper chalk of the north of France; and in the neighborhood of Mons, notwithstanding a thickness of 500 ft. to 900 ft. of strata charged with water, the lower chalk shut the water out so effectually that the coal measures were worked in perfect safety, and were found to be perfectly dry under 1,200 ft. of these strata combined. No part of the straits exceeded 186 ft. in depth.

Mr. Prestwich therefore considers that it would be perfectly practicable, so far as safety from the influx of the sea water is concerned, to drive a tunnel through the Palœozoic rocks under the channel between Blanc Nez and Dover. The circumstances are not so unfavorable as at Whitehaven, where galleries have actually been wrought through the coal for 2 miles under the sea. But while, in the case of the London clay, the distance seems almost an insurmountable bar, in the Palœozoic strata the depth becomes a formidable difficulty. These are the main conditions which bear on the construction of a submarine tunnel between England and France. Mr. Prestwich said he was satisfied that on geological grounds alone it was in one case perfectly practicable, and in one or two others it was possibly so; but there were other considerations besides those of a geological nature, and whether or not they admitted of so favorable a solution was questionable.

Supposing that, when considered from a geological point of view, the construction of a tunnel seemed practicable—yet there were great and formidable engineering difficulculties—but when the vast progress made during the last half century in engineering science was considered, these difficulties would appear to be not insurmountable, especially if the necessity for the tunnel should arise and the cost was not a bar.

HOW TO PREVENT EXPLOSIONS IN COAL MINES.*

By JONATHAN HARRISON.

From "The London Mining Journal."

To insure safety in mines there must not only be a good plan of the workings with adequate ventilating power, but there must also be vigilant administration of all the mining affairs, united with due subordination of authority, constant inspection, and efficient discipline, for danger is always to be looked for and always to be provided against. The first care of an underviewer—whose business it is to descend the mine daily and see that all is right in the ventilation and general management—must be not to allow the gas to accumulate; nor should it be built up, as it is always a source of danger, which wants avoiding in all mines. If gas is found it must be instantly arrested, and removed by ventilation, either by brattice cloth, bricked work, or packed gob roads or headings.

Men should not be allowed to blast with powder in a fiery mine unless they understand ventilation; also, the men who have the care of the stalls should be competent men, as they have the charge of the workings in the absence of the underviewer or deputy; and great care ought to be taken not to allow large caverns to be left, as such places get filled with gas, and a sudden fall of the barometer, with a large fall of roof, taking place both at once drive the gas out, thereby causing a large body of gas to unite with the passing current already loaded with gas, causing the same current to be overcharged, and rendering the same explosive, and the first defective lamp or

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* Being one of the essays written in competition for the Hermon Prizes.

naked light coming near causes an explosion.

To prevent explosions in mines which give off great quantities of gas no air-ways ought to be packed less than 6 ft. by 7 ft., so as to allow the area to be 42 ft.; main returns should have 80 ft. area, and all intakes 70 ft. area; and in mines where all the coal is got out waste packings should be wedged down and built up in the benks 10 ft. apart, to allow the roof to settle more steadily and regularly; also to make it more safe the whole of the gob or gobbing should be made up with refuse sent down the mine, if the workings do not make sufficient to fill up all cavities; but this would incur greater expense in getting the coal. I have known deputies to find gas in the stalls, gate ends, and in the benks, and the men have had safety-lamps, and changed their heated lamps for cooler ones, the men thinking they are quite safe under all conditions; but such things ought not to be allowed, as the men ought to know that gas passing at 11 ft. per second will explode a Davy lamp, which would show them there was danger; but supposing it is a Geordie lamp, and one should be brought into a stall, gate, or benk that has been injured by being crushed, an explosion will take place because of its liability to explode in a current of gas passing at 21 ft. per second. Many scientific men have frequently been directed to that subject, resulting in the publication of much valuable information, and many safety-lamps have been offered for approval; but the general results of experiments and investigation seem to be that the only effectual prevention of explosions must be sought in more efficient means of ventilation, by proper supervision and ordinary care to get plenty of fresh air down the mine, which would be the best safety-lamp. The causes which most frequently vitiate the air are the respiration of the workmen, the combustion of the lamps, the explosions of powder, the spontaneous decomposition of certain mineral substances, such as the sulphurets, which change into sulphates; the coal, which heats and burns spontaneously; the corruption of the wood, the striking of the tools against rocks which contain ores of arsenic or mercury; in addition to which is the natural disengagement of deleterious gases, which penetrate the rocks or are accumulated in the crevices and natural cavities, and sometimes in old workings. The gas thus produced or disengaged disposes itself in the drifts or galleries, according to the order of density, as follows:

Carburetted hydrogen, fire-damp, or inflammable gas	0.555 sp. grav.
Azote, or nitrogen gas.............	0.976
Atmospheric air....	1.000
Sulphuretted hydrogen............	1.191
Carbonic acid or choke-damp	1.524

The general precautions employed to get rid of those gases as soon as they are found in creating currents sufficiently active to effect their diffusion with the atmospheric air, and to draw the mixture out of the works before it is prejudicial, constitute the art of ventilation. When the workings of the mine are commenced, and if no particular phenomena facilitate the renewal of air, the respiration alone of the men and the combustion of their lamps are not slow to modify it sensibly—in fact, a workman respires on an average 210 gallons of air per hour, from which he absorbs in part oxygen, and substitutes for oxygen in that space of time 6½ gallons of carbonic acid, his lamp operating with the same intensity as his respiration produces as much carbonic acid, and augments besides the proportion of unconnected azote. The carbonic acid, or choke-damp, which is thus the most immediate and most general product of the workings in the mine, is recognized by its weight; it always occupies the lowest parts of the excavations; its intermixture with air manifests itself by the difficulty of combustion in the lamps, whose flame diminishes in brilliancy in proportion as the acid increases, and ends by extinction when the mixture attains to 1-10th. The carbonic acid manifests itself upon the miners by an oppression which overwhelms them; nevertheless, habits and temperament will greatly vary the proportion of the mixture which some men are able to breathe. Azote, or nitrogen gas, is much less to be dreaded than the carbonic acid, because its action upon the mineral economy is less energetic; besides, its productions can only take place by the absorption of oxygen from the air, and it does not naturally exist in the fissures or cavities of the rocks.

The ordinary lamp of the miner is extinguished when the air contains no more than 15 per cent. of oxygen (the atmospheric air is composed of 21 per cent. of oxygen and 79 per cent. of azote); it is also at this proportion of 85 per cent. of azote that asphyxia, or suffocation, is caused.

Azote manifests itself by the red color of the flame of the lamps, which ends by extinction; it renders perspiration difficult, produces a heaviness of the head, and a hissing or singing in the ears, which seems a mode of action different from that of carbonic acid. Light carburetted hydrogen, or inflammable air, is of all the gases the most dangerous, and that which occasions the greatest number of accidents, chiefly from its property of igniting when in contact with lighted flames, and of exploding when it is mixed in certain proportions with atmospheric air. The action of this gas upon the flame of the lamps is the most certain guide in ascertaining its pressure and proportion. The flames dilate, elongate, and take a bluish tint, which can readily be distinguished by placing the hand between the eye and the flame, so that only the top of it can be seen. As soon as the proportion is equal to a 12th part of the ambient air the mixture is explosive, and if a lamp be carried in it will produce a detonation proportionate to the volume of the mixture, therefore the most violent explosions take place when a volume of light carburetted hydrogen gas is mixed with seven or eight volumes of atmospheric air.

Light carburetted hydrogen gas is principally found in mines of coal, escaping from the cells of this mineral with a slight noise, analogous to that produced by water immediately before boiling; it is generally disengaged in the greatest abundance in places which are in the neighborhood of faults, near which the nature of the coal is often found to be altered. There are also in the interior of coal beds cavities where the gas is pent up under considerable pressure, and from which it escapes suddenly whenever the side of the cavity nearest to the workings is weakened by their approach, so as no longer to be able to withstand the internal pressure.

The coal beds most dangerous are those which are the most valuable for their good qualities. The abundance of fire-damp in some mines is such that to obtain a natural light nothing more is necessary than to bore a small hole in a coal seam, insert a tube, and a perpetual flame may be obtained. Such is the bituminous nature of the coal, and though the system of ventilation at some collieries (where the greatest number of explosions take place) may be considered by the officials of the most perfect kind, yet a careful and continual watchfulness and knowledge of dangerous symptoms must be constantly exercised by the officers and men in the mine, to enable them to proceed with any degree of safety in such a situation, where, on the smallest error, or a contingency unforeseen, as a boy asleep or at play, a heated lamp, a broken wire, a sudden eruption of gas, or a change in the wind, or a sudden eruption of the atmosphere, whether from the falling of parts of the roof or otherwise, the bounds of safety can no longer be preserved, but, tremblingly alive to their danger, they are plunged unresisting victims into the abyss. The state of a mine may be ascertained with a degree of nicety by the combined indications of the barometer, thermometer, and the anemometer. When the barometer indicates a fall, the thermometer a rise, and the wind blows from the E.S.E. or S., an ordinary fiery mine will be certain to pass rapidly into a state of great danger, and particularly mines subject to blowers should not be worked when the barometer is below 29 deg.

As regards the practical part of the workings of mines in all fiery districts a shaft should be sunk 11 ft. in diameter, and when practicable two shafts of the same dimensions should be sunk at the same time, and a third shaft so soon as the coal is proved, the third shaft to be 16 ft. in diameter, to be sunk on the basset of the workings for an upcast shaft, which would be required for 300 acres of coal, and four shafts to be sunk for 600 acres, and so on in proportion. Also I am convinced from experience that in fiery mines to the depth of 400 yards, fans from 30 to 40 ft. in diameter should be used for ventilation, two fans at the upcast and one fan at the downcast, so to have one in readiness in cases of emergency, and in mines more than 400 yards in depth fans of greater dimensions in proportion should be used, and where furnaces are used they should be fed with plenty of fresh air. The workings of the mine ought to be laid out in sections. [A large and well-executed plan for laying out a mine accompanies the paper.] Each section to have its own ventilating current, so that if an explosion should take place in one part of the mine it could be prevented from extending to the other parts of the mine by special air-ways ripped and packed through the goaves or old workings in a separate return, extending to the upcast and exhausting fan, and in fiery seams headings should be driven to the boundary of the workings so as to bleed the gas, and where gas blowers are known to prevail bore-holes, or little shafts, should be sunk down to the lower coal or shale beds, from which gas often proceeds. Sometimes it lies in cavities, with a very great pressure on the measures, causing the gas to give off in gates, air-ways, and benks, in which case the Geordie lamp should be used with strict discipline, and a barometer should be kept at the bottom of the shaft, also in the centre of the air-way, so that the deputy would be able to examine it as he passes through the works; and where coal lies at a great depth a great quantity of water is to be met with, which incurs an enormous expense in sinking; in such cases iron pipes, 30 in. in diameter, should be taken down the shafts into the old workings to exhaust the gas out.

In getting the coal on the long wall system, it would allow the goaves to be filled up with the roof and holing refuse, which will prevent the gas from accumulating, and where that system can be practically introduced it is essential for the safety of the mine. The long wall system can be worked from 50 to 500 yards in depth under good, bad, wet, or dry roofs, the stalls varying from 30 to 90 yards in length. I have examined scouring which has been done for 10 or 20 years, and I have found the goaves quite firm and safe, and no caverns left for the gas to accumulate in. In the timbering of mines we have special men to set and draw the wood, and I should always enforce the Special Rule—*i. e.*, to have props set, whether the roofs require them or not. I would not advise any air split to be less than 3,000 cubic feet of air per minute. I am quite aware that there are difficulties to contend with in introducing new systems into some districts, both with the men and the nature of the mines.

It is from experience, careful watchfulness, and study to insure the safety of lives in mines, which led me to write this Essay, to carry out your wishes, and satisfy you if possible, in this noble object, in munificently encouraging men to give their ideas to the world, with a view to prevent explosions in coal mines.

In concluding, I consider that a gentleman who has a seat in Parliament should be appointed as a Minister of Mines, with a staff of eminent mining engineers with whom to consult, to be called a Mining Board, and all colliery proprietors should send in their plans of mines before they commence sinking, so as to have the approval of such Minister and the Mining Board. Such plans to consist of the extent of the estate, the size and number of shafts to be sunk, and also a plan of the proposed workings; also such Minister to have power to appoint Inspectors of Mines, and either add to or diminish their number as the Board may think fit. Also such Board to have power to grant certificates to underviewers of the first and second class, according to their qualifications; and such underviewers who are competent to hold certificates should have power to form a local mining board to give certificates to deputies who are qualified; we should then have a staff of well-trained men, and after time has been given for such qualifications no underviewer or deputy should hold situations of responsibility who do not hold certificates; because upon them depends the practical working of the mines, as one or the other is supposed always to be in charge of the mine, therefore they require a special training, also better facilities for the improvement of the men and the education of the boys employed in mining, which would enable them to think as well as to act in their daily occupations.

FLOW OF WATER IN PIPES AND VESSELS.

By H. T. EDDY, C. E.

A recent attack upon the received theory of hydrodynamics suggests a restatement of the mathematical investigation upon which it depends.*

As is well known, any computations of the amount of water which will be discharged from a given set of pipes or communicating chambers can be only approximate; for the resistance of friction, and the resistance which the water experiences by a sudden change of direction on entering or

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* See article on "Hydraulics as an Exact Science," by H. Heineman, in Vol. VI., p. 198, of "Van Vostrand's Engineering Magazine."

leaving a pipe or passing an orifice, are to some extent variable quantities. Their variation depends principally upon the size and shape of the pipes and orifices, and upon the velocity and temperature of the water flowing through them. These resistances have been made the subject of much experiment, the results of which may be found in the works of Weisbach and other authors. By the experiments certain coefficients are obtained which are applied to modify the formula expressing the "theoretic flow," which is the flow on the supposition that there is no resistance experienced from friction, etc. It has been customary to introduce a "coefficient of efflux" for each orifice which the water passes, and also a "coefficient of friction" for each pipe traversed, which coefficients are made to depend principally upon the dimensions of the orifices and pipes, varying as they do but slightly with a change of velocity or temperature.

It is our present purpose to investigate and discuss this formula of theoretic flow.

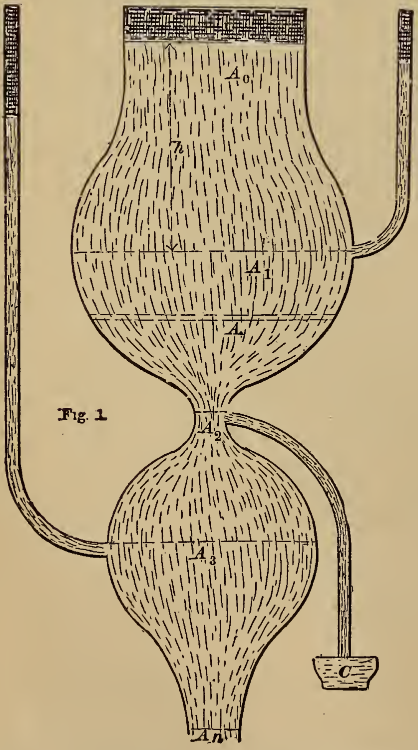

Fig. 1.

Fig. 1 represents a vessel of varying cross-section which is so short and has so large a diameter that the friction is inconsiderable, and in which the direction of flowing water is changed by easy curves, so that the coefficients of efflux are also small. With such a vessel it is possible to produce the apparently paradoxical results hereafter mentioned.

Let A = the area of any cross-section of the vessel.
A_0 = the area of a particular cross-section of the vessel.
A_1 = the area of another cross-section of the vessel.
A_2 = the area of another cross-section, etc.
And A_n = the area of the orifice of discharge.

Let v = the velocity of flow in the cross-section A.
v_0 = the velocity of flow in the cross-section A_0.
v_1 = the velocity of the flow in the cross-section A_1, etc., etc.
And v_n = the velocity of discharge from A_n.

Let p = the actual pressure per square unit in the cross-section A.
p_0 = the actual pressure per square unit in the cross-section A_0, etc.
And p_n = the actual pressure per square unit in the cross-section A_n.
p_a = the pressure of the atmosphere per square unit.

Let h = the height of A_0 above A.
h_1 = the height of A_0 above A_1, etc., etc.
h_n = the height of A_0 above A_n.

Let g = the acceleration of gravitation.
γ = the weight of a cubit unit of water.
Then $A\,dh$ = volume of an elementary lamina of water.
$\gamma A\,dh$ = weight of an elementary lamina of water.
And $\frac{\gamma}{g} A\,dh$ = mass of an elementary lamina of water.
$A\,dp$ = difference of pressure between the upper and under sides of an elementary lamina of water.

Now if we neglect the effect of friction and efflux, *i. e.*, sudden change of direction, the two causes remaining to control the flow are the weight of the water and the greater pressure at one cross-section than another. That there is less pressure at one cross-section than another is clear in the case of a syphon where the pressure is less in the tube the greater the height above the free surface, or in the case of a Torricellian vacuum, where we find the same thing. It may be easy to see that a similar condition of pressure exists in a tube conveying water when the lower part of the tube is capable of conveying away water more rapidly than can be supplied by the upper part. And further, that this cause is always acting to modify the flow in any vessel, so that we may call $A dp$ the *resist-*

ance which the elementary lamina A experiences.

Hence,

$A\,(\gamma\, d\,h - d\,p)$ = the elementacy force of descent.

Now $\frac{\text{force}}{\text{mass}}$ = acceleration.

$$\therefore \frac{A\,(\gamma\, d\,h - d\,p)}{\frac{\gamma}{g}\,A\,d\,h} = \frac{g\left(d\,h - \frac{1}{\gamma}\,d\,p\right)}{d\,h} = \text{acceleration of the water.}$$

But $\frac{d^2\,h}{d\,t^2}$ is the general expression for acceleration.

$$\therefore \frac{d^2\,h}{d\,t^2} = \frac{g\left(d\,h - \frac{1}{\gamma}\,d\,p\right)}{d\,h} \quad . \quad . \quad (1.)$$

Again $\frac{\text{space}}{\text{time}}$ = velocity. $\therefore \frac{d\,h}{d\,t} = v \quad . \quad . \quad (2.)$

Differentiating (2) with respect to t we have

$$\frac{d^2 h}{d t^2} = \frac{d\,v}{d\,t} = \frac{d\,v}{d\,h} \cdot \frac{d\,h}{d\,t} = \frac{d\,v}{d\,h}\,v \text{ by (2)}$$

$$\therefore \frac{d^2 h}{d\,t^2} = v\,\frac{d\,v}{d\,h} \quad . \quad . \quad . \quad (3.)$$

Combine (1) and (3), then

$$\frac{g\left(d\,h - \frac{1}{\gamma}\,d\,p\right)}{d\,h} = \frac{v\,d\,v}{d\,h}$$

$$\therefore d\,h - \frac{1}{\gamma}\,d\,p = \frac{1}{g}\,v\,d\,v \quad . \quad . \quad (4.)$$

The effect of the algebraic work from (1) to (4) was to eliminate t from the equations.

Equation (4) contains three variables, either two of which may be considered to be independent, and the third dependent upon those two. In order to integrate (4), let h and p be the independent variables, and since they are independent, let p be for the moment constant, $\therefore d\,p = 0$, then

$$d\,h = \frac{1}{g}\,v\,d\,v \quad . \quad . \quad . \quad (5.)$$

And integrating we must add some function (at present unknown) of p.

$$\therefore h = \frac{v^2}{2\,g} + f\,(p) \quad . \quad . \quad (6.)$$

Now differentiating (6) it must be identical with (4), if (6) is the integral of (4).

$$\therefore d\,h = \frac{1}{g}\,v\,d\,v + \frac{d}{d\,p}\,[f\,(p)].d\,p \quad . \quad (7.)$$

Comparing (4) and (7) we have

$$\frac{1}{\gamma}\,d\,p = \frac{d}{d\,p}\,[f\,(p)].d\,p \quad . \quad . \quad (8.)$$

Divide this by $d\,p$ and clear of fractions, then (8) becomes

$$\frac{1}{\gamma}\,d\,p = d\,[f\,(p)] \quad . \quad . \quad (9.)$$

Integrate (9) and

$$\frac{p}{\gamma} + c = f\,(p) \quad . \quad . \quad (10.)$$

in which c is the constant of integration. On substituting this value of $f\,(p)$ in (6) we have

$$h - \frac{p}{\gamma} + c = \frac{v^2}{2\,g} \quad . \quad . \quad (11.)$$

Taking this general integral between any two cross-sections as A and A′, *i. e.*, between the limits h and h', p and p', and v and v', we have,

$$h^1 - h - \frac{p - p'}{\gamma} = \frac{v^2 - v'^2}{2\,g} \quad . \quad . \quad (12.)$$

Which equation expresses all the relations between depth, pressure and velocity, for any two cross-sections, as A and A′.

Since the same amount of water evidently passes every cross-section during a second, $A\,v = A'\,v' = A_n\,v_n$ = amount of discharge per second.

$$\therefore v = \frac{A_n}{A}\,v_n \text{ and } v' = \frac{A_n}{A'}\,v_n\,,$$

and combining these with (12) we have

$$h' - h - \frac{p' - p}{\gamma} = \left[\left(\frac{A_n}{A'}\right)^2 - \left(\frac{A_n}{A}\right)^2\right]\frac{v_n^{\,2}}{2\,g} \quad (13.)$$

And from (13) we obtain

$$v_n = \left[\frac{2\,g\left(h' - h - \frac{p' - p}{\gamma}\right)}{\left(\frac{A_n}{A'}\right)^2 - \left(\frac{A_n}{A}\right)^2}\right]^{\frac{1}{2}} \quad . \quad . \quad (14.)$$

Equations (13) and (14) express all the relations which the area and velocity at the orifice of discharge have to the depth, pressure, and areas of any two cross-sections as A and A′. Suppose for instance that A = A′ as in cylindrical tube leading from the bottom of a reservoir, then from (13)

$$h' - h = \frac{p' - p}{\gamma} \quad . \quad . \quad (15.)$$

If the end of the tube from which the water flows is immersed so that the tube is always full, h' and p' may be supposed to refer to the orifice of discharge and then are constant. Equation (15) may then be written

$$h = \frac{p}{\gamma} + c \quad . \quad . \quad (16.)$$

From which it will be seen that p is less, near the top of the tube, and as the lower end is approached the pressure increases until it becomes that of the atmosphere at the orifice of discharge.

In equations (13) and (14) let A′ coincide with A_n, and A with the surface A_0, and let both be open to the pressure of the atmosphere, then $p = p' = p_a$ and $h = 0$

$$\therefore h_n = \left[1 - \left(\frac{A_n}{A_0}\right)^2\right]\frac{v_n^{\,2}}{2g} \quad . \quad (17.)$$

and

$$v_n = \left[\frac{2gh_n}{1 - \left(\frac{A_n}{A_0}\right)^2}\right]^{\frac{1}{2}} \quad . \quad . \quad (18.)$$

Equation (18) is established by Weisbach by a different method, and its validity is disputed by the writer referred to at the commencement of this article, who, among other objections, states that when $A_n = A_0$ then v_n is infinite, which is an absurdity; therefore the formula is untrue. This is the case of a cylindrical pipe, discussed under equation (14), and this or any other of these equations can only apply to vessels or pipes which are kept throughout full of water, for our investigation is only respecting full vessels. The absurdity is in thinking it possible to pour in water at the top of a cylindrical tube in sufficient quantities to keep the tube filled through its entire length.

The writer referred to gives as the correct formula

$$v_n = \left[\frac{g\,h_n}{1 - \frac{1}{2}\left(\frac{A_n}{A_0}\right)^2}\right]^{\frac{1}{2}} \quad . \quad . \quad (19.)$$

But it is to be noticed that when $2\,A_0^{\,2} = A_n^{\,2}$, *i. e.*, when the tube is larger at the lower end than at the upper in the ratio of $\sqrt{2} : 1$, the same absurdity is found in (19) also.

Again, suppose the orifice of discharge is minute compared with the surface A_0, then $\frac{A_n}{A_0} = 0$ nearly.

$$\therefore v_n = \sqrt{2\,g\,h_n} \quad . \quad . \quad (20.)$$

In case the water passes a cross-section of small dimensions as at A_2, let A′ coincide with A_n, and A with A_2, then (13) and (14) become

$$h_n - h_2 - \frac{p_n - p_2}{\gamma} = \left[1 - \left(\frac{A_n}{A_2}\right)^2\right]^{\frac{1}{2}}\frac{v_n^{\,2}}{2\,g} \quad (21.)$$

and

$$v_n = \left(\frac{2\,g\left(h_n - h_2 - \frac{p_n - p_2}{\gamma}\right)}{1 - \left(\frac{A_n}{A_2}\right)^2}\right)^{\frac{1}{2}} \quad (22.)$$

When $A_2 < A_n$, the second member of (21) is negative, and may become so large numerically as to make $p_2 = p_n$ or even $p_2 < p_n$. Now $p_n = p_a$ the atmospheric pressure. ∴ p_2 may be so small that when a hole is made in the side of the vessel at A_2 no water will escape. This may be shown experimentally by noting the height at which a column of water (called a piezometer) can be sustained at A_1, A_2, A_3, etc., by the pressures p_1, p_2, p_3, etc.

Let z_1 = the height of the piezometer at A_1.
z_2 = " " " A_2. etc.

Then

$$z_1 = \frac{p_1 - p_a}{\gamma} \text{ and } z_2 = \frac{p_2 - p_a}{\gamma}$$

When $p_2 < p_a$, z_2 is negative, and water may be drawn from the cup C as if the piezometer and vessel formed a syphon. This may be seen by coloring the water in the cup.

Let A′ coincide with A_2, and A with A_0, then since $h = 0$ and $\frac{p_2 - p_a}{\gamma} = z_2$ (13) becomes

$$h_2 - z_2 = \left[\left(\frac{A_n}{A_2}\right)^2 - \left(\frac{A_n}{A_0}\right)^2\right]\frac{V_n}{2\,g} \quad . \quad . \quad (23.)$$

which shows that the effective head z_2 can never be equal to the hydrostatic head h_2. except when the second member of (23) is nil. This can occur when the velocity $v_n = 0$, or when the areas $A_2 = A_0$. Thus pipes in which water runs are more liable to burst when the water is stopped.

The same laws hold, viz. (13) and (14), when the vessel in Fig. 1 is tipped or bent, provided h and h' be measured vertically to the centres of A and A′, and provided the diameters of A and A′ are small compared with h and h'. Suppose the vessel to be of such a shape that the two cross-sections A and A′ of (13) and (14) are at the same level, then $h' = h$, and we have, if A′ also coincides with A_n

$$\frac{p_n - p}{\gamma} = \left[\left(\frac{A_n}{A}\right)^2 - 1\right]\frac{v_n^{\,2}}{2\,g} \quad . \quad . \quad (24.)$$

and

$$v_n = \left(\frac{2\,\frac{g}{\gamma}\,(p_n - p)}{\left(\frac{A_n}{A}\right)^2 - 1}\right)^{\frac{1}{2}} \quad . \quad . \quad (25.)$$

We can apply (24) and (25) to the discharge through a divergent conical tube, as seen in Fig. 2.

It has long been known that so long as the water fills a tube like this to the cross-section A_n say, that A_n must be regarded as the orifice of discharge and not A_2.

Experiments* by Mr. J. B. Francis, at Lowell, Mass., on the discharge of water through a submerged divergent tube similar to that in Fig. 2, showed such a discharge as to necessitate a value of $p_2 = 0$.

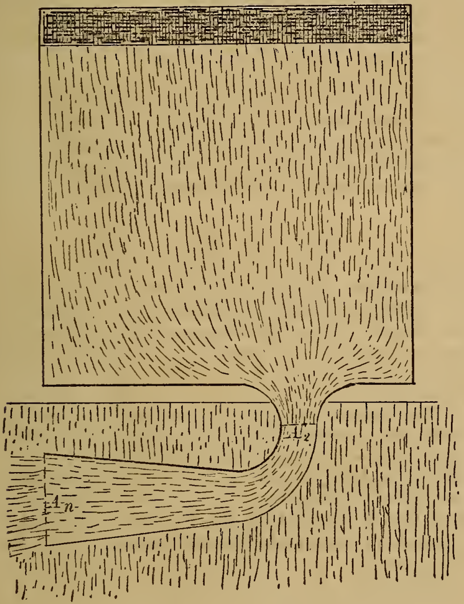

Fig 2

The advantage of a discharge under water is that the submergence insures the filling of the tube by the flow for a much longer distance than can be attained in air.

Application of these same formulas can be made to "Boyden's Diffuser," described in the same work, which is a divergent ring-shaped chamber to receive the water discharged from a turbine wheel, and to remove it at a pressure lower than it would otherwise have been discharged. It acts like a series of divergent tubes around the discharging circumference of the wheel.

Thus the effective head is made to approximate somewhat to the hydrostatic head.

Still further use is made of this principle in turbines to secure a water-tight joint where the water is fed to the wheel. The wheel and "feed" have apertures so proportioned to those which discharge from the wheel, that the internal pressure is nearly that of one atmosphere at the joint; thus there is hardly any tendency to lose water.

Equations (13) and (14) apply also to the case of water urged at A_0 of Fig. 1, by any force, as a piston, causing a pressure p_0 of one, two, or any number of atmospheres, while at A_n the water may be discharged into a receiver at a pressure p_n either less or greater than p_0.

Again, the same equations apply to any incoercible fluid, as mercury, oil, alcohol, etc.

It is useless to urge the insufficiency and absurdity of a theory which covers so wide a range of facts as this, and facts, too, which can each and all be subjected to exact experiment, if it can be shown that the facts corroborate the theory.

I think we are in a position to affirm positively that when such corrections are made for friction and efflux as other experiments show we must make, there is a substantial agreement of theory and experiment.

REPORTS OF ENGINEERS' SOCIETIES.

Architectural Association (London).—At the last meeting of the members of the Architectural Association, held at its rooms, Conduit Street, Regent Street, W., Mr. Richard Moreland, C. E., read an important paper on "Iron Construction," in which he said that with regard to cast-iron pillars in long columns the transverse section had two duties to perform, viz., to support the load and to resist flexure, so that only one half of the strength of the pillar could be considered available for the resistance to crushing, and the other half for the resistance to flexure. In other words, one-half was in compression and the other half in tension: and this was precisely the condition in which a girder was in; or it might be taken as a question of leverage, the length of one end being the diameter of the pillar, and the other half-length of the column; but in the case where the pillar was large in comparison to its length, then the whole of the material must be taken to resist the compression of a considerable portion of its crushing strength. The working load on pillars should not exceed one-tenth to one-sixth of their breaking, and, under ordinary circumstances, should not exceed 25 diameters. Special care should be taken when the pillar was subject to transverse strains, where heavy goods of unstable form were piled against them, as a considerable strain might be produced from this cause; and also in the event of blows from rolling goods or other causes. Pillars in juxtaposition to brick walls took the whole load when they were strong enough to bear it; but masonry served to stiffen the pillar if secured to it: but if the wall was built in cement, and of considerable thickness in comparison to the iron

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* See "Lowell Hydraulic Experiments," by J. B. Francis, C. E. Second Edition. Van Nostrand.

pillars, they then possibly might assist each other. In cases where the brickwork was liable to be compressed, and the pillar unequal to its load, then obviously nearly the whole weight must be discharged on the pillar; but care must be taken, as possibly intense compression might take place at the base of the pillar. The basis should be as level as possible. Short columns under crushing force were deformed by pyramid wedges forming at the ends and forcing out wedges at the sides; this was also seen in the crushing of stone and other solid materials. For various forms and sections of pillars, and also of different lengths, the strength of the material would vary considerably under the diverse conditions in which it was placed. For small proportions of length to diameter, cast iron was the strongest material, but its strength diminished, as the proportion of length to diameter increased, faster than wrought-iron; and in comparison of solid square or wrought-iron pillars, with solid round cast-iron pillars beyond twenty-six and a-half diameters, wrought iron was stronger. For ordinary work no cast-iron columns should exceed twenty-seven diameters. The elasticity of cast iron was twice as great as that of wrought iron. The strength of girders to resist resilience was proportional to the weight of the beam, irrespective of the length, so that a beam twice the weight or twice the length would take twice the load to produce the same deflection. Rolled girders were only economical up to a given size and weight.

He then referred at length to the wrought-iron trussel girders placed over the dining-hall at De Keyser's "Royal Hotel," and said that, in designing the outline of the iron work of these beams, Mr. Greening, the architect of the building, had several objects in view. The thickness of the floors through which the structure was fixed should not be thicker than the other floors, and that, generally, the girders comprising the truss should be limited in depth, so as not to interfere with the heights of the various rooms; the central space, too, should be quite open. The two side spaces being occupied with chimney breasts and flues, economy of space and material, together with great rigidity, were thereby attained. The construction of the six trusses must be briefly described. Two wrought-iron girders were taken for upper and lower members of the truss, and distanced apart by two vertical girders, and so dividing the space into nearly three equal parts. From the junction of the vertical girder with the upper girder to the ends of the lower girder another wrought iron girder was placed at an angle, and securely bolted and secured at the ends. Each of the long girders, independent of the truss construction, would be able only to support its own area of floor, say 1 to 1½ cwt. per foot; but by the employment of these girders as upper and lower members to the construction, these, by the addition of about the weight of one girder and a half, were made to support a load of ten times that which they would carry by themselves. The three lower girders were placed immediately above the dining hall; the lower girder was only 10 in. deep, 12 in. wide; the upper girder was 16 in. deep, 12 in. wide; the length was 30 ft. 3 in.: and the span between walls 35 ft. 6 in.; and the whole height was 9 ft. 3 in. The distance between the vertical rods was 15 ft. 6 in., so that a space was given of 7 ft. 1 in. high by 15 ft. 6 in. wide. In the centre of the girders the diagonal trusses were of the same section as the lower girder. The sectional area of the lower girder and trusses was 46 sq. in., and deducing 8 in. for rivets, gave a net sectional area of 38 sq. in. The upper girder had a gross section of 48 in., which was all available for compression. The foot of each diagonal was bolted to the lower girder and an angle casting was also secured to it and the lower girder; and similar castings were also fixed at the junction of the vertical girders with the upper end of the diagonals. Each separate piece of the truss was riveted together and laid in position, the corner castings fitted, and the whole of the holes drilled, after being carefully put together; and the various portions were then fixed in their respective positions and securely bolted together. The summary of the load on the girder was 200½ tons.

IRON AND STEEL NOTES.

CHEMISTRY OF THE BESSEMER PROCESS.—The conclusions reached by Kessler in regard to the theory of the Bessemer process may possess some interest to our metallurgical readers, since they differ somewhat from the views generally advocated.

The observer in question finds that in the Bessemer process of steel-making the entire amount of carbon present at first is relatively increased, owing to the more energetic oxidation of certain other substances in the iron in the earlier portions of the "blow," and that the carbon first begins to oxidize after the major portion of the silicon has disappeared.

Concerning phosphorus—the most obstinate impurity—Kessler declares that its amount is decreased during the middle portion of the process, but that its proportion is relatively increased both at the commencement of the "blow," owing to the more energetic oxidation of the other impurities, and towards the end of the operation, when it is, to some extent at least, taken up again from the slag. Sulphur decreases rapidly at first, but increases again in the middle stage, up to the addition of the spiegeleisen, for the reason that a portion of it, which in the first stage went into the slag, is afterwards taken up again by the iron. When the spiegeleisen is added and the "blow" recommenced, the sulphur again diminishes, and the suggestion is made that if it were possible to remove the first slag, which, contains much of the sulphurous impurities, it would be possible to use brands of iron which are known to contain sulphur for making Bessemer steel.—*Journal of the Franklin Institute, Philadelphia.*

IRON TRADE IN READING.—In this country there is capacity for making 3,000,000 tons of pig iron per annum, including the run of the new furnaces, completed this year; and since we can no longer draw to any extent upon the British market, which is taxed to supply the Continental and other demands, that amount should not exceed the annual requirements. With the country's present mileage, 700,000 tons of new and re-rolled rails will be required for renewals during 1874, and this is within less than 100,000 tons of the present maximum capacity of the rail mills. To this must be added the amount needed for the extensions, sidings, etc., for new roads which are far advanced, and for additional tracks which some of the trunk lines already find necessary for the separate accommodation of freight and passenger traffic. The market is now almost wholly relieved of foreign rails. The importations have practically ceased, and as prices on the other side are likely to be maintained, they cannot be sent here profitably in competition with the American product. This leaves the field pretty much to our own iron masters, and the probabilities are that the demand this year will keep them well employed, even though we should build less than a quarter of the mileage completed in 1872. In that year about one-third of our total production of iron went into railroads, and, with foreign supplies practically cut off, there seems to be no good reason for supposing that we shall not want as great proportion in 1874.

MISSOURI IRON PRODUCT.—The statistics for 1873 show a marvellous and most gratifying progress in the manufacture of iron in this State. In 1870 the United States Census reported in Missouri 15 blast furnaces, employing $1,914,000 and yielding $586,293. In 1873 we have 12 establishments, with 18 furnaces, $5,783,000 capital, employing 2,421 hands, paying $1,089,300 wages, and yielding 100,000 tons of pig, valued at $4,500,000, and 120,000 tons of rails, valued at $1,008,000,—a total of $5,508,000. Thus in three years the capital employed in iron and rail making has trebled, the number of hands has more than doubled, and the product has been increased fourfold. Our State has gone into iron making in earnest, and as iron can be produced cheaper here than in either Pennsylvania or Ohio, we may confidently expect that the next Census will show Missouri one of the leading iron States.—*St. Louis Republican.*

THE HENDERSON PROCESS FOR THE MANUFACTURE OF WROUGHT IRON.—Messrs. Cooper, Hewitt & Co. have completed arrangements for the manufacture, at their mill in Trenton, N. J., of wrought iron by the Henderson process, and as soon as the necessary supply of fluorspar shall have arrived at the mill, they will be prepared to fill orders for any quantity of this iron which may be required by the trade. This process, which has merited and received the commendation of the most scientific and successful iron masters of Europe, and which has now been adopted by one of the best known firms in the iron trade of this country, opens a new and inviting field of enterprise to the American iron manufacturer. By it ordinary qualities of pig iron may be made into wrought iron of superior purity, softness and ductility, at a cost but little exceeding that of ordinary puddling, and very much cheaper than the price of corresponding grades of Swedish and British iron in this market.

There is no wrought iron now made in this country which is a substitute for the high class Swedish iron for the manufacture of tools and cast steel of the best qualities, and large quantities are annually imported for these uses. The reason that the Swedish irons are better than other kinds is, that they are nearly pure, and are consequently very soft and ductile. The same results are had when any kind of pig iron is treated so as to render the wrought iron pure. This, however, is not possible by the puddling process; but other means have been discovered to effect this object. We have noticed at different times results obtained by the use of the Henderson process, and we have recently had ample confirmation of what we have before written about it. This process yields a pure, soft and ductile wrought iron, even when using ordinary or inferior pig iron. It has the high tensile strength of the superior qualities of Yorkshire bar combined with the softness and ductility of the Swedish, and is, therefore, of superior value for all purposes to which wrought iron is applied. Its purity has been shown by chemical analysis, and its strength, softness and ductility by mechanical tests in testing machines. Softness is ascertained by the amount the specimen contracts at the point of rupture, and ductility by the amount that it stretches before breaking.

NOTES ON THE DEFINITION OF STEEL.—The author remarks that it is time to fix the terms of a good definition of steel. As far back as 1869 he proposed to reserve this name for all *malleable siderurgical products obtained in a state of fusion*, reserving the term "iron" for every malleable product which has not undergone fusion. From this definition, it follows that the ancient steels, with the exception of cast steel, can be regarded merely as irons more or less carburetted and steely. Cast steel, as well as the new metals bearing the names of Bessemer, Siemens, Martin, etc., are the only true steels having the characteristic of being obtained in a liquid state, and run into homogeneous and compact blocks or ingots. Homogeneity and compactness, natural consequences of the liquid state, are the two characteristics of these metals, and belong to steel only. It is well known that masses of crude iron result merely from the juxtaposition of grains of iron at a comparatively low temperature, amidst a slag more or less liquid. By the processes of shingling and rolling, the greater part of the impurities are squeezed out of this metallic sponge, and the particles of iron are brought sufficiently near to each other to be more or less perfectly welded together. Thus a rough, crude outline of iron is obtained—the primitive form in which iron is met with in commerce, and which is very different from that of crude steel. The latter, obtained at an extremely high temperature, is composed of small drops of iron, more or less completely carburetted, entirely exempt from slag, and forming, when cool, a homogeneous and compact block or ingot. It is the high temperature attained which impresses a peculiar character on the new metals. In fact no other means is so effectual for expelling slag and rendering a metallic mass homogeneous. In practice, the distinctions just pointed out cause the difference of the uses to which iron and steel are put. If the manufacturer requires a metal capable of resisting wear and tear, iron will not be selected. Mere juxtaposition of particles implies want of compactness, and probability of exfoliation and roughness of surface. This is the case with rails, especially at stations, inclines, and crossings, and with all articles exposed to great friction. If, again, a metal is required capable of bearing shocks and prolonged vibration, steel, if the respective tenacity is equal, is still superior to iron. The want of compactness of the latter involves the beginnings of fissures, which go on increasing till the article is fractured. There are multitudes of purposes for which the homogeneity of steel renders it preferable to iron, in spite of the difference of price. It must not, however, be supposed that steel is destined to supplant iron, especially as the new methods of mechanical puddling will place the latter in an improved position, bringing it a step nearer towards the homogeneity and compactness which are characeristic of cast steel.

At present, siderurgical industry yields two series of products, identical in chemical composition, but differing in the manner in which they are obtained. The first is the scale of irons, commencing with common iron in its different states, passing then to granular iron of different qualities. Next steely iron or puddled steel often so rich in carbon as to admit of being tempered. Sometimes even it is scarcely malleable, like Styrian steel. This is a species of refined cast metal, obtained in furnaces fed with wood, and so far freed from carbon that a single balling in the furnace renders it capable of being shingled—though with difficulty, and then drawn into steel wire of the first quality. At the top of this scale we must also place the cementation irons or steels, which are only irons highly carburetted by the immediate contact of carbon.

The second series forms the scale of steels. It is parallel to the foregoing, and each of its members is analogous to a member of the iron scale. It begins with extra soft steel, which welds like iron, and does not take a temper. Next follows soft steel, corresponding to granular iron and semi-soft steel, representing puddled steel. Lastly comes a hard steel corresponding to the cementation irons or steels, and to Styrian steel. This final number of the scale welds badly and tempers readily. The following table shows the percentage of carbon for both series:

Percentage of Carbon.—0-0.15, 0.15-0.45, 0.45-0.55, 0.55-15.

Series of Irons.—Common irons, granular irons, steely irons or puddled steel, cementation iron or steels, Styrian steels.

Series of Steels.—Extra soft steel, soft steel, semi-soft steel, hard steel.—*Iron.*

Novelty in Forges.—One of the greatest difficulties that a smith has to contend with in the working or welding of large forgings is the danger of burning part of the iron in endeavoring to obtain a good working or welding heat throughout a considerable mass. This burning, we need scarcely say, has the most deteriorating effect upon the tenacity and elasticity of the iron; and there is little room for doubt that this frequent burning of forgings is the cause of many deplorable accidents to apparently sound cranks, axles, etc.

This great danger in working is caused principally by our present arrangement of ordinary forge hearths. The air-blast is generally introduced by a single tuyere-pipe only, so that the side of the forging presented to the blast will burn long before the other side is cherry red, if the forging be large. The constant attention of the smith is thus required, and considerable labor, also, for the continual turning and moving of the iron to present all sides as often as possible to the blast.

We have just noticed a very simple and neat forge by Messrs. Seel and Shaw, in which the pipe from the air chamber is divided underneath the hearth, and *two* tuyere-pipes are led therefrom into opposite sides of the hearth. This will afford a much more regular heating throughout the mass of a large forging, and the arrangement has given excellent results in practice. The tuyeres are well protected by a water-jacket, which circulates from a cistern placed at the back of the forge.—*Iron.*

RAILWAY NOTES.

The Narrow Gauge in the United States.—We have received from W. W. Nevin, Esq., of Philadelphia, who is connected with the management of the Mexico National Railway Company (the Palmer project), a statement of the progress, and an estimate of the prospects of narrow-gauge construction in the United States. The paper being too extended for reproduction in these colums, we take the liberty of presenting a *résumé* of its chief subject-matter. Col. Nevin characterizes the narrow gauge as a "railway reform movement," which may now claim as accomplished facts: 1. A saving in the first cost of construction about 33 per cent. 2. A saving in operation which shall make the net earnings average 50 per cent. of the gross instead of 33, which has so far been a liberal average for good completed roads. 3. The ability to reach sections where it is physically impossible for roads of the wide gauge to be built at all. With the questions of relative dead and live weight and maximum carrying capacity, next considered, our readers are familiar.

The statistics of construction are especially valuable. The total length of projected narrow-gauge roads in America is given as 4,680½ miles (3,889½ in the United States, and 791 in the Canadas), and of this there are completed 1,364½ miles; 928½ in the United States, and 436 in Canada, as follows:

In the United States.

Name.	Miles built.	Total length.
Denver & Rio Grande	156	870
Cairo & St. Louis	92	150
Utah Northern	70	160
Kansas Central	65	560
Arkansas Central	64	150
Colorado Central (N. G. Division)	42	237
North & South of Georgia	35	130
Montrose	27	27
Ripley	26	36
At Johnston (Private)	25	25
Cherokee, Alabama	23	45
Iowa, Eastern	20	183
Milwaukee & Des Moines	20	300
American Fork, (Utah)	18	22
Pioche, (Nevada)	18	18
Central Valley	12	12
East Broadtop	12	30
Mineral Range, Michigan	12½	100
Wasatch & Jordan Valley	12	16
Pittsburgh & Castle Shannon	8	8
Bell's Gap	8½	40
Peekskill Valley	7	7
Summit County, Utah	8½	30
Tuskegee	5½	30

Louisville, Harrod's Creek, & Westport	5	28
Painesville & Youngstown	12	65
Baltimore, Swan Lake, & Towsontown	6½	6½
Peachbottom	5	60
Bingham Cannon & Salt Lake	20	20
Ceredo Mineral, W. Va	12	20
Cheraw & Salisbury	11	80
Lawrence & Evergreen	5	5
Echo & Coalville, Utah	9	9
Natchez, Jackson & Columbus	6	260
Galena & Southern Wisconsin	30	150
	928½	3,889½

The following were to have completed additional mileage by Jan., 1874.

Cairo & St. Louis	52
Des Moines & Minnesota	17
Parker's Landing and Kansas City	10
	1,007½

In the Canadas.

Name.	Miles built.	Total length.
Toronto, Gray, & Bruce	199	200
Toronto & Nipissing	87	218
New Brunswick	70	170
Prince Edward's Island	90	203
	433	791

The following list is given of

Roads actually under Construction:

Name.	Under construction.	Total length.
Florida, Memphis, & Columbia	120	260
Lexington, Lake & Gulf	170	170
Wyandotte, Kansas City & N. Western	50	250
Cairo & Tennessee River (under construction in Duck River Valley, Ala.)	75	100
South Branch (W. Va)	26	51
Cheraw & Salisbury	15	80
Nashville & Vicksburg	26	470
Bainbridge, Cuthbert & Columbus	20	140
California Central	150	465
Des Moines & Sioux City	20	180
Salt Lake, Sevier Valley & Pioche	25	300
Alameda, Oakland & Piedmont	60	60
St. Louis & Manchester	8½	30
Juan, San Pete & Sevier	10	75
Washington, St Louis & Cincinnati	65	950
Greenville & Paint Rock	5	22
Stockton & Ione (California)	36	36
St. Louis & Western	100	315
Denver & Rio Grande	50 miles	graded.
Utah Northern	90 "	"
Arkansas Central	86 "	"
North & South of Georgia	60 "	"
Summit County (Utah)	3½ "	"
Peachbottom	45 "	"
Ceredo Mindral (W. Virginia)	6 "	"
Natchez, Jackson & Columbus	14 "	"

The following

Projected Roads

are organized and more or less under way:

North Pacific Coast	250
Big Sandy Valley	137
People's Narrow Gauge of Iowa	170
Minneapolis, Rochester & La Crescent	140
St. Louis & St Charles	14
Holly Springs, Brownsville & Ohio (being graded)	
Long Island Narrow Gauge	
Toledo & Maumee	
Northern & Southern Narrow Gauge, N. C.	
St. Louis & Florissant	16
The South Park Railway, Col	260
Tennessee Central	
Memphis & Raleigh	

English and American Railways.—The London "Railway News" has some interesting comparisons of English and American railway returns, and in the matter of rolling stock and train earnings is surprised to find the American roads more economically run than the English. Taking four roads in each country, aggregating about 4,000 miles, it is found that the American road has only .33 of a locomotive and 6.72 freight cars per mile, while the English has .93 of a locomotive and 28.83 cars. The New York Central, with a heavier traffic than the London and North Western, has half the locomotives per mile. The English refuse to believe that the superior size and strength of American locomotives account fully for this difference. The earnings, for instance, of an American locomotive are 70 per cent. more than those of an English, and the entire rolling stock, which in England barely pays for itself in a year, in this country pays for itself and 65 per cent. more. The "News" also discovers that, while passenger fares are 30 per cent. lower than in England, the earnings per train here are 4 per cent. more, and on freight trains 15 per cent. more, than on the English roads.

ENGINEERING STRUCTURES.

Engineering Construction on the Continent.—In the way of projects, the Geographical Society of France has received a communication which is startling in its novelty; it appears that there exists from the gulf of Galeès to the meridian of latitude in which the town of Biskra lies, a series of vast depressions called *chotts*, which would be lakes, only there is seldom any water in them. They extend over a length of 180 to 190 miles, with width varying from 12 to 36 miles in width, and the edge of one of them, at least, is more than 80 ft. below the level of the sea. It is believed that at some remote period the whole of these depressions were filled with salt water, and as the first is only separated from the gulf of Galeès by dunes of small extent, it is proposed to cut a canal, and let the waters of the Mediterranean into this vast series of hollows, provided that a survey of the whole of the *chotts* should prove that they are really in connection with each other. The advantages set forth are the creation of sea-ports 50 miles south of Bliskra, the surveillance of the nomad tribes of the south which at present defy the power of France, the consequent domination of the lands to the south of Constantine, and the eventual drawing of the commerce now carried on with Central Africa, by the Touareqs, by way of Tunis, Morocco, and Tripoli. Captain Roudaire concludes by asking the authorities to appoint four surveyors—two to start in one direction, and two in the other, and says that the actual state of the depressions may be ascertained thus in about 100 days.

M. Richard's plan for forming a ship canal to Paris is now more fully before us. The projector calculates that the canal being once filled sufficient water must be provided for the transport of 1,250,000 tons of imports and 750,000 tons of exports, or on an average 3,000 tons each way per diem. This quantity of water he sets down at 60,000 tons per diem, to which must be added loss by evaporation, by the locks, and by infiltration, making a grand total of 135,000 tons per diem, for that part of the canal lying between Dieppe and the river Oise, to which M. Richard adds 25 per cent. future increase of traffic. For the upper portion of the canal—that between the Oise and Paris, M. Richard calculates on a business of 12,000 tons per day in both directions, and a consequent demand for 185,000 tons of water. He says that the lower part of the canal can be fed from the rivers Eaune, Bethune, and Arques, and the upper arm from the Seine. The total length between Dieppe and Paris is reduced by certain modifications in the original plan to 94 miles, and the cost is estimated at £51,200 per mile. The cost of establishing the port of Paris is given at nearly a million sterling, and the total cost of the whole work at £6,000,000. The port is to cover an area of 675 acres, or more than that of the London docks.

A curious experiment is being tried on the railway bridge across the Seine at the Pont du Jour, with the view of diminishing the great weight of ballast on railway bridges and viaducts; stout canvas is nailed down on light wooden cross-pieces and covered with bitumen, the surface of which is closely covered with small stones, such as are found in garden mould, so as to prevent accident from sparks.

THE BALTIMORE BRIDGE COMPANY.—An incorrect statement in our January issue regarding the work done by this Company is corrected by the following, viz.:

They have built since commencing business in 1866,

Of Wrought Iron Viaduct	20,565	lineal	ft.
" Fink Truss	12,934	"	"
" Triangular Truss	10,127	"	"
" Quadrangular "	9,129	"	"
" Girders	2,256		
Total (single track)	55,011 ft.		

ORDNANCE AND NAVAL.

CLYDE SHIPBUILDING.—Recent issues of "Iron" give some interesting facts relative to the condition of the shipbuilding industry at its great European centre. A period of slackness has occurred there, lasting for several months; but in September a revival set in, a large number of fresh contracts having been made with various shipbuilding firms for vessels of large size. Curiously enough, a reaction in favor of sailing vessels has taken place, resulting from the high price of coal, and a large proportion of the new iron ships are to be propelled by the air alone. Messrs. M'Millan & Son, Dumbarton, have in hand two iron sailing vessels of 2,200 tons each, for a Liverpool house engaged in the East India trade. When they are launched these will be the largest iron sailing ships afloat. In the early part of November there were 91 vessels on the stocks in the Clyde shipyards, and the builders had every reason to anticipate an increase in their orders instead of the predicted decrease.

The number of vessels launched from Clyde shipyards in September was considerably below the average of the past 9 months, but the tonnage was largely in excess of that launched in any corresponding month. There was an increase of 1,600 tons over the tonnage launched in the same month last year, and fully 4,000 tons over the average of several years, while in the past 9 months there was an increase of 24,000 over 1872, and 41,000 tons over the average of the four preceding years, as shown by the following table:

	Month.		Nine Months.	
	Vessels.	Tons.	Vessels.	Tons.
1873	12	18,600	119	184,500
1872	11	17,000	143	160,500
1871	11	11,800	131	133,300
1870	15	16,000	148	137,000
1869	14	12,500	158	142.000

There were launched from the Clyde shipbuilding yards during October, 14 vessels, the aggregate tonnage of which amounted to 20,150, which is fully 2,000 tons less than was launched in the same month last year; however, the tonnage is fully 3,500 tons more than the average launched in the 4 years 1869—1872 in the same month. The following tabulated statement indicates at a glance the position of the trade, so far as launches are concerned, for a period of five years from the present time:

	Month.		Ten Months.	
	Vessels.	Tons.	Vessels.	Tons.
1873	14	20.150	133	204,500
1872	17	22,250	1[illegible]0	182.800
1871	13	17,600	144	150.000
1870	8	7,200	156	144,000
1869	22	19,000	189	160,100

—*Nautical Gazette.*

SAFETY AT SEA.—A NEW SUGGESTION.—A correspondent, A. W. C., who appears to have given some attention to the subject, thinks we are greatly behind-hand in our methods of ocean navigation, and suggests an improvement. In reference to such a loss as that of the Ville du Havre, he asks if it be not time to discard the useless contrivances which are proposed as life-saving, and render the steamers themselves a kind of life-saving mechanism. "The truth is," he says, "the steamer herself should be a life-saving contrivance, built in such a way, or of such material, that she could not sink, even if cut in two, or filled with water to her upper deck. In other words, has not the time arrived when there should be for the exclusive conveyance of passengers and mails a style of vessel that would cross the ocean in a week or less, with absolute security against foundering and fire?

"The ocean steamer of to-day is simply a huge freight-boat. She is somewhat larger, and perhaps a trifle swifter, but certainly not any safer, than when she first crossed the Atlantic, some thirty years ago. And for the chance passenger of those days she did well enough. But look for a moment at the present enormous volume of ocean travel. Doubtless, more have crossed during the last ten years than crossed in all the previous centuries since the time of Columbus. And yet in no department of human industry has so little real progress been made in the last quarter-century as in this.

"It would certainly seem absurd if our railroads had no passenger cars, and we had to travel about the country strapped on to the roof of a freight car. Ocean travel is quite as absurd and even more dangerous, for our tier of state-rooms is strapped on to the top of a heavy iron box, loaded with heavy freight, which, in the event of a sudden blow, goes to the bottom as if it were made of glass. And with all human foresight and caution, such collisions with other vessels or with ice will sometimes occur.

"As to the material, the model and the dimensions of the coming ocean steamer, these are problems which marine engineers must work out. What most naturally suggests itself is a vessel of about the same length as now in use, but broader and shallower, with lines adapted, not to carrying capacity, but to speed; the chief novelty, however, being that the entire hull, excepting the space required for engines and coal, would be filled up with very small air-and-water-tight compartments or cells. Perhaps as much as three-fourths of the entire interior would be devoted to this cellular arrangement, so that the ship would be, in effect, a gigantic life-preserver. All the passenger accommodations, as well as the sailors' quarters, etc., would be upon the main deck.

"The cellular construction of the vessel would add greatly to her strength, while her lightness would admit, at least in ordinary weather, of great speed, and her model would greatly diminish the rolling so provocative of sea-sickness.

"The chief question, of course, is the expense. If it won't pay, it won't be done. It must be remembered that, while the first cost and the running expenses per day would not exceed those of the present style of steamer, the passenger steamer could make twice as many trips in the year, for she would not only be actually faster, but would save much time between voyages which is now spent in discharging and receiving cargo. For the same reason, there being no cargo, she could, after landing her passengers at Plymouth or Brest, start again in a day or two on her return trip. Her passenger accommodations would no doubt be greater than at present, and the mails would add much to the receipts. Besides this, people would pay more for a short voyage to Europe than for a long one, and the feeling of security is worth more than a trifling difference in money.

"It is not contended that such a vessel could not be wrecked. She might be disabled by collision or stranding, but it is hardly possible that she could be sunk by any form of accident that we are familiar with.

"It is to be hoped that before the end of the present decade we shall see the present cumbrous steamers given up entirely to the freight business, for which they are so well adapted, while we ourselves shall glide rapidly across the ocean in vessels which, in the event of accident, we can at least depend upon remaining afloat."

We give the suggestions of our correspondendent for what they are worth, remarking simply that they have at least the merit of originality and interest.—*Evening Post.*

BOOK NOTICES.

A PRACTICAL TREATISE ON THE SLIDE VALVE BY ECCENTRICS. By Prof. C. W. MACCORD. New York: D. Van Nostrand.

The author—Prof. C. W. Mac Cord, of the Stevens Institute of Technology—has evidently endeavored, and with marked success, to supply a want felt, probably, by every student of mechanics, by every young draughtsman, and by every ambitious young workman. A book which, concisely yet clearly, gives a knowledge of the principles involved in this form of valve-movement, and instructs its readers in the methods of "laying out" the valve and its motion on the drawing-board, has long been needed.

Algebraic analysis was applied at a very early date, to the expression—mathematically—of the law governing valves moved by eccentrics; but it is not algebraic expressions that a draughtsman desires. He is compelled to translate these formulæ into geometrical constructions, and he does his work by the use of a purely goemetrical language. For this purpose, therefore, a geometrical treatment is far more satisfactory than the algebraic, even when, as is not always the case, he finds no difficulty in comprehending the less familiar language, or in making an accurate translation from it into his own. The author of this treatise refers to this fact in the text, and has fully recognized it in the method he has adopted. Himself an accomplished draughtsman, he confines himself in his work to the methods of the craft, and, by the use of neatly made diagrams, has exhibited the processes of geometrical construction applicable to the problem to be solved, representing the several parts in their proper relative proportions and positions. Restricting himself to this task, he has produced a work which is as useful to the student as it is creditable to the writer. The attention is not distracted by the consideration of the relative proportion of the size of the valve to that of the engine, or to the limits of its applicability as an expansion valve. These points are beyond the intended scope of the work.

The movement considered is simply that derived from a single eccentric with direct connections, and no allusion is made either to the link motion or to the various forms of regulating or reversing gear. The one aim is everywhere kept in view—to teach, as completely as possible, the principles of the slide-valve motion governed by a single eccentric: this result is fully attained.

The author states that needless mystery is usually thrown around this subject through the assumption that the three-ported valve is essentially a single detail, and by the introduction at the outset of the consideration of the irregularities produced by the action of the connecting rod and the eccentric rod, so that the beginner is bewildered, if not disheartened, before he has fairly entered upon his task.

Showing that this valve, in reality performing four distinct functions, may be regarded as a combination of four distinct organs, which again may be considered separately, he endeavors to smooth the path of the learner, by at once dividing it into its component parts, and taking them up singly in their order.

In the first chapter, a graphic investigation of the general character of the motion derived from an eccentric is given, entirely divested of the complications produced by the eccentric rod, and the different ways in which a valve may be made to open and close a port are thus clearly shown, as well as the limits of its action and the peculiarities to be noted in each case.

The systems employed in practical every-day work are next considered, their treatment being rendered equally simple and satisfactory by the conceptions already obtained. Consistently adhering to the synthetic method, both in treatment and in the arrangement of the work, the author first defines his valve as a contrivance governing one port for a single purpose—that of regulating the admission of steam at one end of the cylinder. The operation of the valve thus limited in its functions is now explained in connection with an engine working without expansion; the modification required to produce expansion by "cutting off" the steam at a specified point is next taken up, and "lead" is subsequently considered.

The author criticises the frequently used expression, "in order to make the valve cut off, we add lap," and shows that the lap is the effect of a primary cause, which cause is the change in the angular position of the eccentric; and indicates that it is most correct to regard throughout, the eccentric as the controlling device. A careful study of this chapter should be sufficient to make clear to the most beclouded mind, the real nature and object of "the lap of the slide-valve."

In the construction of the diagrams, the condition that the case considered is that in which there is no angularity of the connecting-rod is continually kept in view by a novel and very neat and effective method of illustration. The diagram exhibiting the motion, is drawn upon and in direct connection with the valve, so that the effect of the eccentric in producing motion is made plainly visible at every step and throughout this course of instruction.

The author then goes on to treat of the motion of a valve operating one exhaust port only, and next shows how two valves may be connected, and operated by the same eccentric, whether both are steam, both exhaust, or one steam and the other exhaust.

It is next shown how, in the last arrangement, the action on the exhaust side is deranged, if the valve is made to cut off on the steam side. Finally the student is taught that when these "disjecta membra," of which the separate movements have been explained, are combined, they form substantially the common slide-valve with its fourfold functions, and that the latter presents no new features, with the two exceptions of the "lead" usually given it, and the "minus lap," which presents itself when the engine having lead is required to "follow full stroke."

The third chapter closes with the introduction of simple and easily comprehended diagrams, teaching how to construct geometrically the "movement" of the three-ported and of the two-ported valves.

Independent and slide expansion valves are next considered. When these valves are placed on the back of the main steam-valve chest, the principles involved in their geometrical treatment are, of course, merely those already explained, and their application is the same, with slight modifications introduced by the peculiarities of each case. When, however, the cut-off valve is carried on the back of the main steam-valve, the movement is usually less comprehended. Here the author has succeeded in presenting a very simple and easily understood illustration of it, and shows how the *relative* motion of the cut-off valve and its moving seat, is precisely that which would result were the latter at rest, and the former actuated by an eccentric rotating around the centre of the other eccentric, which, in fact, actuates the main valve. This novel and neatly effective method reduces the whole to a very simple problem, and it is easily seen that this device is practically identical with the preceding. Here, as in the other cases already referred to, the relative positions of the valves are depicted on the movement diagram, and the whole system is exhibited with admirable clearness.

The concluding chapter treats of the irregularities due to short connecting and eccentric rods, and teaches how to lay out the three-ported valve movement when it is desired to cut off at a given point, with the lead fixed for one end of the cylinder.

As a whole, the work is well adapted to the wants of a large class of readers. Its author uses it in instructing the classes of the Stevens Institute of Technology, and it will equally well meet the wants of other institutions of a similar character.—*American Artisan.*

ANALYTICAL CHEMISTRY.—A Course of Analytical Chemistry (Qualitative and Quantitative), to which is prefixed a brief treatise upon Modern Chemical Nomenclature and Notation. By WM. W. PINK and GEO. E. WEBSTER. London: Lockwood & Co., Stationers' Hall-court, Ludgate-hill. For sale by Van Nostrand.

Although the progress of the student of chemistry will always depend to a considerable degree upon the ability of the teacher, the use of a good outline treatise much lessens the labor of storing the facts in the memory in readily available form. A work well calculated to serve this purpose has just been issued as one of the volumes of Weale's educational series, and although extending to only 170 pages an enormous number of facts concerning both qualitative and quantitative analyses are carefully given. In the preliminary remarks concise information is given as to the theories adopted by the South Kensington authorities with reference to molecules and bonds, and there is a well-arranged list of the Frankland bonds of most of the common elements, classified according to their highest known atomicities, added to which is the very necessary explanation that, although an artiad can never become a perissad, nor a perissad an artiad, yet the pentads frequently take the form of triads or monads, and the hexads of tetrads or diads. Cases are given in which all the bonds are engaged, and the molecules complete, as well as of those in which the bonds are connected to the bonds of an atom of a similar element, those where we have a diad atom's bonds satisfying each other and forming a monatomic molecule, and those in which the two latter cases occur simultaneously. There is a list of the more important compound radicals, hydroxyl, hydrosulphyl, ammonim, ammonoxyl, sodoxyl, zincoxyl, and potassoxyl. These, with a couple of pages of rules for formulating, and a brief explanation of the theory of equations, complete the introductory matter. The notes on general analysis are equally clear and concise, and a large mass of really useful information is given, which will enable the student to economize his reagents, and avoid damaging his apparatus. Ample particulars are also given as to the impurities to be looked for in the reagents, and the method of preparing them for use. The mode of separating the elements contained in a given compound into groups is, of course, given, and by the use throughout the book of various kinds of type, and the graphic formulæ usually of the science teachers of the Kensington School, the passing of the examinations used by educational departments will be much facilitated by using the book.

The volume is at once concise and explicit, and those who use it with the assistance of a science teacher, of even moderate ability, can scarcely fail to satisfy the examiners, and attain a creditable position in the class list.

A MANUAL OF INORGANIC CHEMISTRY. THE NON-METALS. By T. E. THORPE, Ph. D. London and Glasgow: W. Collins, Sons & Co. For sale by Van Nostrand.

The collection of facts which constitute the modern science of chemistry is so immense that it is not surprising that Professor Thorpe has been compelled to divide his text-book into two volumes. The work before us is one of Messrs. Collins' advanced series, and it is admirably calculated to fulfil its design of fitting a student to take part in a study of current chemical literature and theories. The author has wisely not contented himself with a *résumé* of well known facts, but has consulted the most recent memoirs of original researches, and has contrived to give, in a small space, an excellent survey of chemical facts and philosophy. This book, besides being one of the cheapest, is also one of the best for the student intending to submit to the Advanced or the Honors Examination in Chemistry of the Science and Art Department.

THE OCEAN: ITS TIDES AND CURRENTS AND THEIR CAUSES. By WILLIAM LEIGHTON JORDAN. London: Longmans, Green and Co. 1873. For sale by Van Nostrand.

There is no more vexed question in physics than that which concerns the causes of the great ocean currents. For a time long in the age of modern science the piling up of the waters of the Atlantic in the Mexican Gulf was universally accepted as the moving why of the best known of the great salt-water rivers, whose banks are also composed of the liquid element which covers five-sixths of the surface of the globe, and forms the highway of the nations; then Captain Maury, and after him Dr. Carpenter, produced their theories, all of them seeking the solution of obvious facts in more or less obscure causes. The author of this book, however, rests his theory upon a cause cosmical in its origin, which he styles "vis-inertiæ," and holds to be "a really inherent property in matter, by virtue of which it endeavors to be just what it is and where it is"—the conservative principle in nature, obviously—"and that gravitation is simply an effect of vis-inertiæ." And on this principle, like the ancients with their abhorrence of nature for a vacuum, he accounts not only for the currents, but the tides both of the ocean and the atmosphere, and not only for these, but for the entire motions of the stellar and planetary bodies—gives us, in fact, a new "Principia.' Still, the book is the production of a man thoroughly well up in his own subject, and many others collateral with it; but from the nature of the argument it is difficult of popular explanation within the limited space at our disposal. It is one, however, that may be safely commended to the study of all who are interested in the subject of ocean currents, regarding which we think we may safely affirm that no hypothesis yet offered covers all the facts of the case.—*Iron.*

MISCELLANEOUS.

CONCRETE CONSTRUCTION.—In the Report by Mr. Thomas Hawksley, past-President of the Institution of Civil Engineers, on the Chester Sewage Works, which was read at the meeting of the town council on January 14, we find the following reference to the system of concrete construction adopted in part of the works:

"The tanks have been designed in a somewhat unusual way, probably with a view to economy; but in my judgment, even in this view, not very successfully. Cement concrete has been resorted to as a substitute for brickwork, and as a substitute it may succeed well enough, provided the persons engaged in the necessary manipulations have had much previous experience in the use of the materials, and take a real personal interest in their work. For my own part, I should have preferred good brickwork for this purpose to any construction of concrete. I do not, however, wish to intimate that there is any danger of the concrete work failing, provided the labor and materials be really of the superior kind to which I have thus alluded. Questions had arisen and were put before me upon this particular subject, and they became extended to the qualities of the lime concrete, and of the mortar as used in the work. I proceed to answer those questions:—

First, as to the cement concrete. This concrete was stated to have been composed in the following *measured* proportions: Gravel, six parts; sand, one part; cement, one part. If the cement were reliable, these proportions ought to result in a first-class concrete. I was informed that the prescribed cement had been difficult to obtain, and that a cement made from the lias limestone of Warwickshire had been used instead. I prefer the lias cement, assuming it to have been properly manufactured, and therefore do not think that the engineer has been unwise in permitting the substitution.

Second, as to the lime concrete. This I understand to have been made in the following measured proportions: Gravel, five parts; sand, uncertain and variable, but small in quantity; Rugby or Holywell ground lime, one part. These proportions form a rich concrete which might have been improved in its finally hardening properties by a larger proportion of sharp sand. I prefer also that the lime and the sand shall be made into a well-mixed mortar before being added to the gravel. The strength of all concrete depends upon the intimate blending of angular sand with the cementitious matter, for without that a proper crystallization is not set up.

Third, as to the mortar. This was stated to consist of: Lime, two parts; sand, two parts; cinders, one part. This was not a good material. The sand was in fact crushed sandstone, and the cinders were really slags of steam boilers. These were ground with the lime under edge-stones till the whole was reduced to an impalpable mixture, rather of the character of a limey mud. For the reasons already stated, the sand should have been sharp, silicious, and angular, whilst, as I understand, the cinders should have been smith's ashes. containing the usual proportion of iron oxide. Hand-made, or well-pugged mortar is to be preferred for engineering purposes to finely crushed mortar.—*Architect.*

EVALUATION, IN MECHANICAL UNITS, OF THE QUANTITY OF ELECTRICITY PRODUCED BY AN ELEMENT OF A PILE.—M. Branly.—The object was to estimate, in electrostatic measure, the quantity of electricity passed, in a second, by an element of a pile, in a circuit of given resistance. An insulated metallic sphere received, *m* times per sec., a constant charge A, which was removed each time, by putting it in communication with the ground by the bobbin of a Ruhmkorff galvanometer. The quantity of electricity, *m* A, traversing the bobbin, deflected the needle; and this deflection was compared with that produced by the flow of electricity from a Daniell element in a known circuit (the method of doing this is detailed). It was verified that the charge of the sphere is proportional to the radius of the latter, and to the potential of the pile, and that the deviation is proportional to the number of discharges (at least within certain limits). After these preliminaries, the author gives numerical particulars of one experiment The number obtained for *m* A is 104,699 units of electricity. The current produced by 104,699 units passing each second to the earth gave a deviation measured by the number 51.25. The current of a Daniell element was passed in a circuit of 1,000 kilometres; and the two wires of the galvanometer were connected to two points of the circuit, comprising, between them, 1 kilometre. The resistance of the galvanometer being 336 kilometres, and the intensity of the principal current being represented by 1, that of the derived current which traversed the galvanometer was about $\frac{1}{336,000}$; for the double deviation (current reversed) the reading was 371.4. It may then be said that the current whose intensity is $\frac{1}{336,000,}$ causes to circulate, in 1 sec., a quantity of electricity represented by $104699 \times \frac{371.4}{51.25}$ units. Before giving a definite number for the constant to be measured, the author proposes to determine, with more precision than he had been able to do, the absolute resistance of the bobbins used.—*Tel. Jour.*

ON THE LOSS OF MAGNETISM.—M. Jamin.—Coulomb has shown that a magnet, heated successively to increasing temperatures, preserves after cooling only a portion, less and less great, of its primary magnetism. The general opinion is, that at a temperature *t*, steel takes a determinate magnetization, which is less as *t* increases, and which it retains on cooling. But the phenomena are in reality more complex and curious. M. Jamin takes a bar of tempered steel; transfers it to a sand bath, where it receives the blue color of springs; then introduces it rapidly into a bobbin of electric wires traversed by a current of 20 elements; and by means of straw suitably arranged, he prevents, or at least retards, cooling of the apparatus. The steel takes a total magnetization slightly less than if it were cold. Then he breaks the circuit, and measures immediately the force of detachment of a contact placed at the end; *i. e.*, the remanent magnetization. Not only is the steel thus magnetized in the hot state, but its remanent magnetism is much greater than that which it is capable of preserving when it is cold. It is equal to 109 grammes, instead of 54. It is not correct, then, to say that the coercitive force diminishes with heating; the contrary occurs. But if one commences to measure the force of detachment minute by minute, it is perceived to decrease at first very rapidly, then less rapidly, and in a quarter of an hour it has wholly disappeared. This occurs not only when the magnet is maintained at its primary temperature, but when it is allowed to cool naturally, which takes place very slowly. There is not, then, for each temperature, a determinate magnetic state decreasing as the heat increases. The passage is almost continuous from total magnetization, represented by A B (line parallel to abscissa in figure given), to the remanent magnetization represented by B C D (curve concave upwards), descending towards zero as the time increases. There is a veritable magnetic loss which is gradual, which resembless the loss of heat in cooling, and may be well enough represented by Newton's law $y = \varepsilon^{-ax}$. Now heat the bar, but to a less temperature, and re-commence the initial magnetization. While the current passes, it is represented by E F (a line higher than A B); but immediately the current ceases, it falls to G (a point some distance below B); it is less than formerly; but, on the other hand, it is weakened less quickly, and is not totally lost; there remains after cooling, a portion which is the greater the less the bar has been heated. Lastly, M. Jamin compares the case in which the bar is not heated. It has a total maximum magnetism K L (line higher than E F), and a remanent magnetism, the smallest possible, and not sensibly varying with the time.—*Tel. Jour.*

WESTERN ILLINOIS BRIDGE.—The plans for the proposed new bridge over the Mississippi at Quincy, Ill., have been prepared by the American Bridge Company of Chicago. It is to be a double-deck bridge with railroad track below and highway above. There will be a draw-span of 300 ft., one fixed span of 250 ft., the other fixed spans being 160 ft. each, and the whole length of the bridge about 2,400 ft.

NOTE.—The article on "Fuel," in the present number of the Magazine, is substantially the same as the article bearing the same title in the last volume. It was received in pamphlet form from a prominent engineer with a request to re-publish entire. It was accordingly sent to the printer, under the impression that the former publication was an abstract only, and was possibly too brief for so valuable an article. A comparison of the two, however, shows that our first was so complete as to have rendered the second publication unnecessary in our columns. The discovery was made too late to effect a change.

VAN NOSTRAND'S
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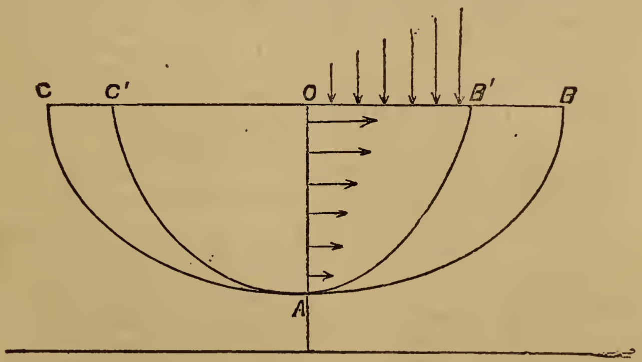
No. LXIV.—APRIL, 1874.—Vol. X.

THEORY OF ARCHES.

(*Continued from page* 200.)

Case VII.—If we construct a curve from the last one by using the same ordinates and by changing all the abscissas in the ratio $c:1$, so that the new co-ordinates of a point shall be y and $c\,x$, and at the same time change the *horizontal* forces in the same proportion, leaving the *vertical* ones unchanged; the new curve and new system of forces so obtained will evidently be parallel projections of the former, and will be balanced. This new curve C′AB′ (Fig. 28) is the "Geostatic," and bears a relation to the "Hydrostatic" strictly analogous to that between the ellipse and circle.

Fig. 28.



Hence,

The total vertical load on A B′ $=$ V′ $=$ V $=$ pull along cord at B′.
Total horizontal load on A B′ $=$ H′ $=$ c H $=$ pull along cord at A′. (35.)

The *intensities* are

$$\text{For } \textit{vertical} \text{ load } p'_y = \frac{V'}{O\,B'} = \frac{V}{c.OB} = \frac{p_y}{c}$$
$$\text{For horizontal load } p'_x = \frac{H'}{O\,A} = \frac{c\,H}{O\,A} = c\,p_x \qquad (36.)$$

(V H p_x and p_y referring to the hydrostatic curve.)

The load at A and B′ and C′ being altogether *normal* (it is not so at the other points), let ρ'_0 and ρ'_1 be the radii of curvature at A and B′.

Then

$$H' = p'_v\,\rho'_0 = \frac{p_v}{c}\,\rho'_0.$$

In the hydrostatic

$$H = p_v\,\rho_0. \qquad \therefore\ c\,H = H' = c\,p_v\,\rho_0.$$

$$\therefore\ \frac{p_v}{c}\,\rho'_0 = c\,p_v\,\rho_0$$

$$\rho'_0 = c^2\,\rho_0 \quad . \quad . \qquad (37.)$$

So

$$V' = p'_x \varrho'_1 = c\, p_x \varrho'_1 = V.$$

But in the hydrostatic

$$V = p_x \varrho_1.$$

$$\therefore p_x \varrho_1 = c\, p_x \varrho'_1.$$

$$\therefore \varrho'_1 = \frac{\varrho_1}{c} \quad . \quad . \quad (38.)$$

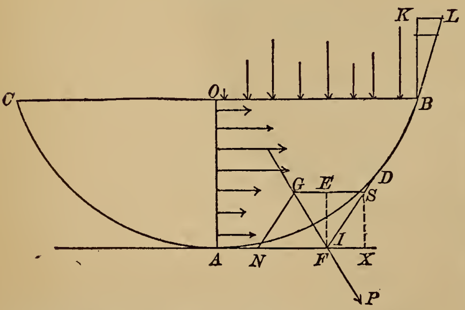
These radii are useful in drawing the geostatic curve.

Case VIII.—So far we have discussed the curves assumed by cords under loads distributed according to some simple law. But it is possible to discuss the more general problem: Given a load that varies and is distributed in any manner, required the curve which it will cause the cord to take; or conversely, given a curve, required the character and distribution of the load to produce it. The most useful form of the problem is that in which we assume the *shape of the cord*, and the *vertical components of the load*, and require to be found the intensity and distribution of the *horizontal components* of the load necessary to produce equilibrium.

To illustrate; assume the curve to be a circle, and the vertical load to be uniform in intensity, we see at once that the horizontal load should be also uniform, and of intensity equal to that of the vertical load.

But generally: Let C A B (Fig. 29) be some assumed curve, and let the vertical load be known in amount and distribution. Making some changes in the signification of the letters heretofore used, now let

FIG. 29.



V = vertical load on any arc A D.
V_1 = vertical load on the semi-cord A B.
H = horizontal load on any arc A D.
H_1 = " " half-cord A B.
H_0 = pull along cord at A (the quantity heretofore denoted by H).
p_x and p_y = the horizontal and vertical intensities as heretofore.
p_0 = value of p_y at the point A.
ϱ_0 and ϱ_1 = radii of curvature at A and B.

The vertical load on an arc A D is

$$V = \int_0^x p_y\, dx \quad . \quad . \quad (39.)$$

Again at the horizontal point A, the vertical projection of the element of the curve being = zero, the load is entirely vertical, and consequently at that point is *normal* to the curve. Hence the pull along the cord at A is

$$H_0 = p_0 \varrho_0.$$

To discuss the forces upon an arc A D. Draw tangents at A and D. They meet at F (Fig. 29), through which point the resultant of the total load on A D must pass. The *vertical load* is also = the vertical component of the pull along the cord at D, for these two forces, being the only vertical ones connected with A D, must needs balance each other. Therefore,

Lay off F N = H_0. Lay off F E vertical and $= \int_0^x p_y\, dx$. Complete the rectangle F E S X. The pull along the cord at

$$D = F S = F E \operatorname{cosec} i = V \operatorname{cosec} i \quad . \quad . \quad (40)$$

Also,

S E = F X $= V \cot i$ = horizontal compound of pull along the cord at D . . (41)

But the horizontal pull at A is

$$H_0 = F N = G S.$$

$\therefore$ G E $= H_0 - V \cot i = H$ = resultant of horizontal load on A D . . (42.)

The *intensity* of this horizontal load may be expressed thus

$$p_x = \frac{dH}{dy} = -\frac{\delta (V \cot i)}{dy} = -\frac{\delta \left(V \frac{dx}{dy}\right)}{dy} \quad (43.)$$

At B the vertical load = V_1. Let this be represented by B K (Fig. 29). If the cord be itself vertical at that point, B K = V_1 will be equal to the pull along it at B. If the cord is inclined as in the figure, draw its tangent at B, and

B L = B K $\operatorname{cosec} i_1 = V_1 \operatorname{cosec} i_1$ = pull along the cord.

and

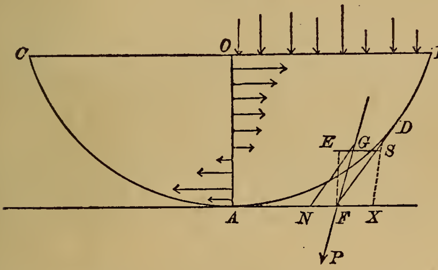
K L = B K $\cot i_1 = V_1 \cot i_1$ = horizontal component of this pull.

$H_0 - V_1 \cot i_1 = H_1$ = resultant of entire horizontal load on A B.

It may often happen that S E = $V \cot i$ = horizontal component of the pull along the cord at D (Fig. 30) is *greater* than G S = F N = H_0 = horizontal pull along the cord at A. In such cases G E = $H_0 - V$

cot i is negative, which indicates that the horizontal load between A and D, for at least a part of this distance, must be contrary in direction to that heretofore discussed; that it must exert an *inward pull* instead of an *outward one* (Fig. 30). If this "inward pull" were removed or replaced by an outward one, the curve would evidently be *flattened* about A.

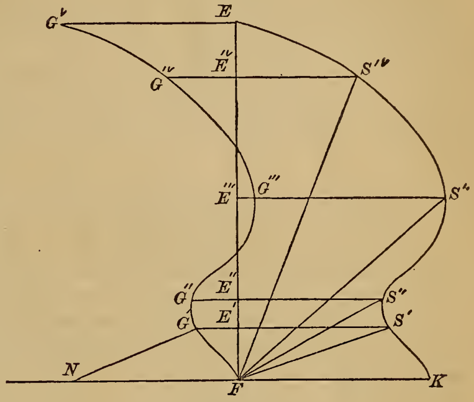
FIG. 30.



We may illustrate geometrically, the relation between the forces in all parts of A B.

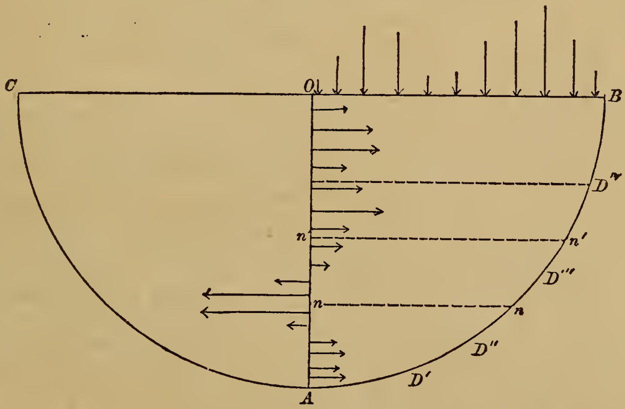
The vertical load and curve being given draw F E^{v} (Fig. 32) = the total vertical load on A B, and lay off on it

FIG. 32.



F E' = vertical load on the arc A D'.
F E'' = " " " A D'', etc.

FIG. 31.



Draw a horizontal line at F and lay off F N and F K, each = H_0 = pull at A. Draw through F lines parallel to the tangents at D' D'' D''', etc., and through E' E'' E''', etc., lines parallel to the horizon. Then the oblique lines F S', F S'', etc., represent the pulls along the cord at D' D'', etc., while E' S', E'' S'', etc., represent the horizontal components of these pulls. Lay off from each point S' S'', etc., horizontal lines, each equal to F N, and draw through the points G' G'', etc., thus obtained, a curve. It will evidently be similar to that drawn through K S' S'', etc., and the line G' E' will represent the resultant of the horizontal load that must be distributed along the curve from A to D'; G'' E'', the resultant of the horizontal load between A and D'', and so on.

(Fig. 32) is really formed from the parallelogram of forces for the arcs A D', etc.; this parallelogram being at D' = F N G' S', in which E' S' is the horizontal component of the pull at D and E' G' = the resultant of the horizontal load on A D'.

As the abscissas of the curve F G' G'', etc., increase to the left of F E^{v} from the point F to G'' (which correspond to D'' on the curve), the horizontal load acts outward on the arc A D''. The abscissas then diminish to G'''. Hence between D'' and D''' on the curve, the horizontal load must act inwards as shown in (Fig. 31). From G‴ the abscissas increase until we reach G^v. Hence the horizontal load acts outward throughout the remainder of the cord. The points n and n' correspond to those arcs on which the resultant of the horizontal load is zero. Thus on the arc A n the *negative* horizontal load is just equal to the *positive*, and hence their sum = zero. So on the arc A n'.

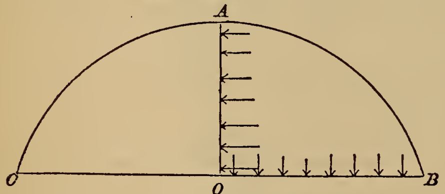
Note that the abscissas of the curve F G′ . . . G^v are not the *intensities* of the horizontal loading, but that each such abscissa represents the *algebraic sum* of the entire horizontal load between A and the point to which the abscissa corresponds. The *intensity* in question has already been shown to be

$$p_x = \frac{d\,H}{dy}.$$

In this expression d H = the difference of two neighboring abscissas of the curve F G′ . . . G^v; as for instance, $d\,H = G'\,E' - G''\,E''$. And dy = vertical projection of the arc D′ D″ of the cord to which the above corresponds.

ARCHES.

FIG. 33.



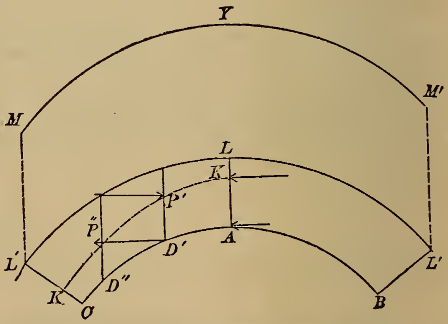
Let us imagine the curve of the cord to be reversed, and the cord itself to be replaced by a thin metal strip, which like the cord shall be practically without transverse stiffness, but, *unlike* the cord, shall be able to resist a compressive force in the direction of its length at every point. Let the loads be distributed as heretofore, except that where there are horizontal components of the load, these should act *inward*, where upon the cord they acted *outward*, and *vice versa*. We then have what is called a "linear arch or rib"; and the curve assumed by it will be identical with that of the cord under equal and similarly distributed loads. If the loading is changed in distribution, the rib will change in shape just as the cord would do under similar circumstances.

In practice there are no "linear arches," but the discussion of them enables us to determine the form of equilibrium for real arches. If we know the form that a *linear arch* would assume under a given load, we can find the "line of pressures" in the real arch. This line and the value of the thrusts at all its points enable us to solve the problems that arise in arch building.

1. Suppose, for instance, we desire to construct an arch to bear a *uniform vertical load*, such as that discussed in *Case I.* The shape of the linear rib under such a load is a parabola. We then as,

1° Step. Assume this curve for the intrados C A B (Fig. 34). If the arch and the load be of homogeneous material, the shape of the *extrados*, or outside of the load, will be M Y M′, the vertical distance between C A and M Y being constant.

FIG. 34.



2° Step. Is to determine the depth A L of the keystone. This depth is always greater than necessary simply to prevent the crushing of the material of the arch under the thrust at the crown. Prof. Rankine's empirical rule derived from the best examples is to make the depth of the keystone in feet

$$\left.\begin{array}{l}\text{In single arches}\\ =\sqrt{.12 \times \text{radius of curva'e at the crown.}}\\ \text{In arches of a series}\\ =\sqrt{.17 \times \text{radius of curva'e at the crown.}}\end{array}\right\} \quad (46.)$$

3° Step. Determine whether the "line of pressures" can lie in the "middle third" of the ring of voussoirs. It should be restricted to the *middle third* to prevent the voussoirs tending to open at any of the joints.

We can test this as follows:

Suppose the voussoirs to be constant in depth all around the arch as in (Fig. 34.) Consider any part of the arch included between the vertical plane (A L) at the crown, and a vertical plane at any other point, as D′ P′. The calculated horizontal thrust along the linear rib, which coincides in shape with the soffit C A, is indicated by the arrow with its head at A. Let the *horizontal thrust* of the rib at D′ be indicated by the arrow with its head at D′ pointing in an opposite direction to that at A. At the crown take A K not greater than $\frac{2}{3}$ A L. Imagine a left-handed couple applied to A L in the vertical plane of the arch, whose force $= H =$ the thrust at A, and whose lever-arm $=$ A K. Apply an equal and opposite couple on the plane D′ P′, with a force H′, equal to the horizontal thrust of the rib at D′. Its lever-arm D′ P′ must then

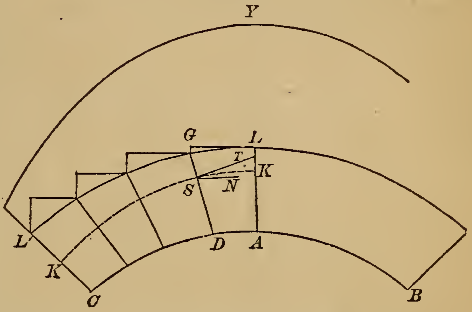
$$= \frac{H . A K}{H'}$$

In the parabola $H = H'$ ∴ $D'P' =$ A K. These couples being equal and opposite do not change the conditions of equilibrium of the section of the arch L D′, but they transfer the line in which the thrust acts from A D′ to K P. We can repeat the process as often as we choose by taking parts L D″, etc.; and if the curve drawn through the points K P′ P″, etc., lies within the *middle third* of the arch-ring, the arch is sufficiently stable.

In the case before us, the horizontal thrust being constant for every point of the rib C A, the lever-arms D′ P′, D″ P″, etc., are also equal, and therefore the "line of pressures" K K′ is merely the parabola raised vertically a distance $=$A K. If K K′ does not lie in the *middle third*, a slight increase in the voussoirs, especially towards the springing, will usually remove the difficulty.

4° Step. The joints between the voussoirs, such as D′ G (Fig. 35) are usually made normal to the soffit A C, but whether this be done or not, the direction of G D′ must be such that at S, where the line of pressures cuts it, the angle included between S N (the normal to G D′) and S T (the tangent at S to K K′) may be less than the angle of friction of the material of the voussoirs. The best possible direction for the joints D′ G, etc., would be to make them perpendicular to K K′.

FIG. 35.



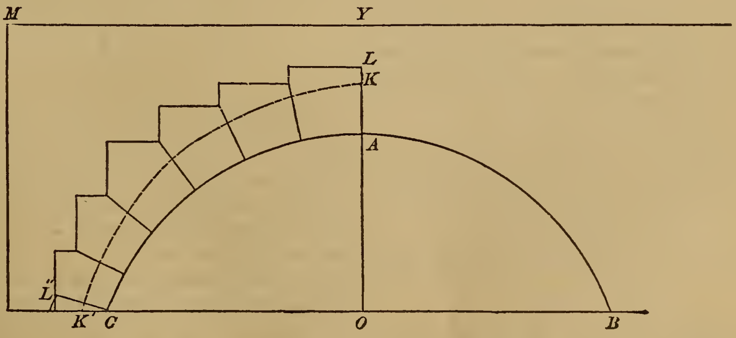
The horizontal component of the thrust (H) along the curve of pressures in a parabolic arch, is, as we have seen, constant; but the thrust along the curve (T) increases from A to C, and its value at any point may be determined by the formulæ in Case I.

Parabolic stone or brick arches are not common, because it is rare to have such a distribution of the load as that supposed above.

2. But if we reverse the curves discussed under Cases II. and III., we have a form of arch much more frequently applicable.

Thus, suppose the arch and its backing to be homogeneous, and that the *extrados* of this loading is horizontal (M Y), and suppose the action of the load to be entirely

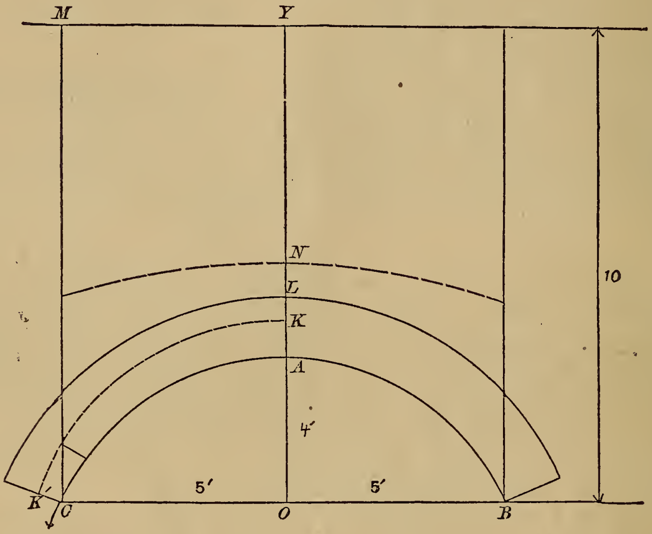
FIG. 36.



vertical. Then the arch and its backing are similar to the metal sheet and the cord discussed in the cases just referred to, and therefore the form of the *linear rib* under such a load will be a catenary or transformed catenary—usually the latter.

Assume this curve for the soffit C A B (Fig. 36); determine the depth A L; the line of the pressures K K′; and the direction of the joints; as in the last case. In this case as in the parabola, H is constant and hence the curve of pressures is merely the curve C A raised vertically through a distance = A K.

Fig. 37.



Example. Let the data for a required arch be (Fig. 37) span C B = 10′; rise O A = 4′; height of extrados M Y above springing at C = 10′. Let the arch and brickwork be of solid brickwork whose weight w per cubic foot = 112 lbs.

The equation of the transformed catenary passing this C A B is

$$y = \frac{y_0}{2}\left\{ E^{\frac{x}{m}} + E^{-\frac{x}{m}} \right\}$$

Where y_0 = A Y = 6′ (the origin being at Y and the axis of abscissas horizontal).

First find m, the modulus of the corresponding common catenary. By Eq. (14.)

$$m = \frac{x'}{\left\{ \frac{y'}{y_0} + \sqrt{\frac{y'^2}{y_0^2} - 1} \right\}}$$

At the point C $x' = 5$ ft. and $y' = 10$ ft.

$\therefore m = 4.54$ ft. = Y N.

Then determine points of the curve, thus for

$x = 1,\ y =$ for $x = 2,\ y =$ for $x = 3,\ y =$
for $x = 4,\ y =$ etc.

Describe the curve through these points.

The thrust at the crown A is (for a unit of length of the arch)

$H = w\,m^2$ from Eq. (16).

$\therefore H = (112)\ (4.54)^2 = 2308.3$ lbs.

From eq. (15) area A Y M C =

$$\frac{m\,y_0}{2}\left\{ E^{\frac{x}{m}} - E^{-\frac{x}{m}} \right\} = 36.32 \text{ sq. ft.}$$

Weight of load A Y M C = P = (112) (36.32) = 4067.84 lbs.

From Eq. (18) thrust at C = T = $\sqrt{P^2 + H^2}$ = 4677.1 lbs.

Inclination at C . Tan $i_1 = \frac{d\,y_1}{d\,x_1} = \frac{y_0}{2\,m}$

$$\left\{ E^{\frac{x'}{m}} - E^{\frac{x'}{m}} \right\} = 1.77.$$

$\therefore i_1 = 60° 32′.$

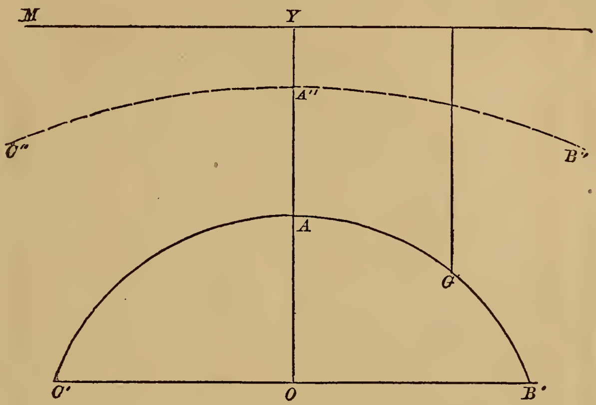
The formula for depth of keystone will be satisfied by making the depth of the arch A L = length of one brick = 9″ for this gives 9″ × 12″ = 108 square inches to bear the thrust H = 2308.3 lbs., or T= 4677.1 lbs. The latter is the greatest thrust in the arch.

It is easy to see that K K′ will be in the middle third, for even at C the distance of the point of the curve K K′ vertically over C, from the nearest point of C A, is approximately

$$6 \times \cos\,(90° - 60°\ 32′) = 5″ +.$$

The *extrados* of the transformed catenary need not be the directrix M Y; it *may* be another transformed catenary *provided these catenaries have the same directrix.*

FIG. 38.



To illustrate: suppose the weight of a unit of the material between C A B and M Y $= w$. Then the intensity of vertical pressure at any point G of C A B (Fig. 38) is $= w\,y$. If a heavier building material were used this vertical pressure could be brought upon G by a less height of it. Let this heavier material have a weight per unit $= w'$ and let

$$w' = \frac{2}{3}\,w.$$

Then a column of the heavier material over G and of a height $= \frac{2}{3}\,y$ would give the same pressure as the whole column of the lighter, or

$$w\,y = \frac{2}{3}\,w'\,y \quad . \quad . \quad (47.)$$

At each point of C A B (Fig. 38) lay off two-thirds of the vertical ordinate, and through these points draw C″ A″ B″. The upper surface of the load may have this form, and yet C A B still be the shape of the linear arch balanced under the applied forces. The equation of C A B being

$$y = \frac{y_0}{2}\left\{ E^{\frac{x}{m}} + E^{-\frac{x}{m}} \right\}$$

that of C″ A″ B″ is evidently

$$y' = \frac{\frac{1}{3}\,y_0}{2}\left\{ E^{\frac{x}{m}} + E^{-\frac{x}{m}} \right\} \qquad (48.)$$

The principle of this example is general. When the *extrados* is a transformed catenary, note that, since in all the formulæ under Case III., $w =$ the weight corresponding to a unit of surface of the space between C A B and M Y, we must make in these formulæ

$$w = n\,w'$$

Where $w' =$ weight of the building material and $n = \frac{\text{A A}''}{\text{Y A}}$.

In arches of this class no provision is needed for horizontal thrust on the spandrels as the arch is equilibrated under vertical loads alone.

In all stone or brick arches, the changes in the curve of pressures K K′ due to passing loads are usually slight, because the weight of such passing loads is generally small compared with the weight of the arch itself and its backing.

3. The simplest practical case in which a uniform normal load (such as that discussed in Case IV.) can be applied to an arch is when it is subjected to water pressure, the arch ring being horizontal instead of vertical. Such a pressure will exist on an empty well constructed in a reservoir or other body of water (Fig. 39). For each horizontal layer of the well wall may be considered as subjected to a uniform normal pressure of an intensity due to the depth of the water at that layer. This intensity will of course diminish (and so will the pressure on the wall) from one layer to another as we come towards the top.

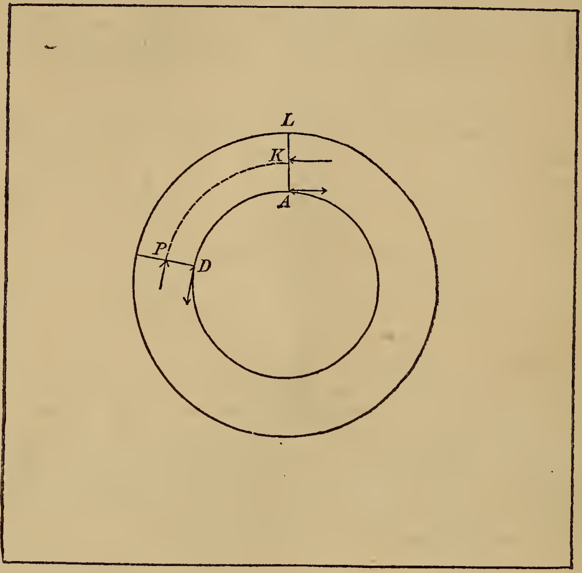
The soffit of such a well should be *circular* from (Case IV). The thickness of the wall at any depth must be determined by the thrust, which is constant all around any given layer and is

$$T = p\,r = w\,y\,r. \quad . \quad . \quad (49.)$$

Where $w =$ weight of a unit of water and $y =$ depth of water at the layer in question.

In determining the line of pressures consider a section of the wall between two vertical planes not parallel as heretofore, but both normal to the soffit. Take for the lever-arm of the couple at A (Fig 39) a distance $AK = \frac{1}{2} AL$. The *force* is still to be $= H = T$.

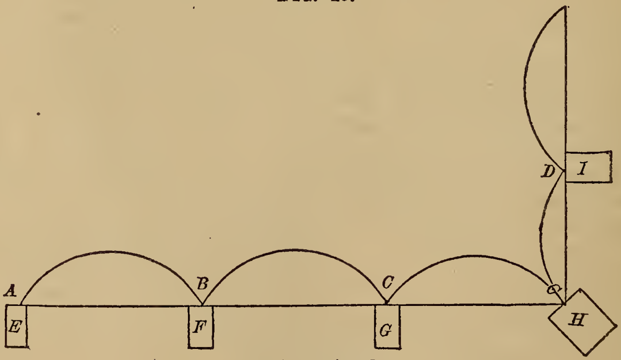
FIG. 39.



At D apply an equal couple with force = the thrust along the soffit at that point, which is also $= T = H$. Then the lever arm must be equal to A K. Hence we see that the curve of pressures is a circle *parallel* to the soffit and may pass through the middle of the arch ring.

This kind of arch may be used for dams or the walls of reservoirs. (See Fig. 40.)

FIG. 40.



(To be continued.)

COMPOUND ENGINES.

BY A. MALLET.

Translated for Van Nostrand's Magazine.*

We devote a few pages to the history of Compound Engines; a history heretofore little known; which we are able to make complete by means of documents that enter into minute details, and which contain matter instructive and interesting, while they

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* Etude sur les Nouvelles Machines a Vapeur Marines. Premiere Partie. Economie de Combustible par Bramwell (Traduction). Deuxieme Partie. Etude sur les Machines Compound, par A. Mallet. Paris, A. Bertrand, Editeur.

shed light upon subjects heretofore obscure.

The idea of employing the expansive power of steam is generally attributed to James Watt. This is shown by the evidence of a patent of Jan. 5, 1769, No. 913. The process consisted in arresting the introduction of steam a little before the termination of the stroke of the piston, thus reducing the pressure at the moment of the reverse stroke; it was not until sometime after that it was perceived that a certain quantity of steam was thus economized.

Jonathan Hornblower, who built the Newcomen engines, patented the use of two cylinders to effect the expansion, on the 13th July, 1781, No. 1298. He said that he employed the steam after its action in the first cylinder in order to employ it in the second expansively.

Here is the original:

"I use two vessels in which the steam is to act, and which in other steam engines are generally called cylinders.

"I employ the steam after it has acted on the first vessel to operate a second time on the other, by permitting it to expand itself, which I do by connecting the vessels together and forming proper channels and apertures, whereby the steam shall occasionally go in and out of the said vessels."

Hornblower's engine met with small success. As it used steam at low pressure it had but a limited expansive power, and the advantages became of no account; rather they became negative on account of the resistances due to the use of two pistons. Besides, he could not use his engine without borrowing most of the parts of Watt's engine, such as the separate condenser, etc. So Hornblower got by means of his invention only the enmity of the friends of Watt, who accused him of indirect plagiarism, and created a bad reputation for him, of which traces are found in the early histories of the steam engine. At this time the use of two cylinders turned out unsuccessful.

But when higher pressure was employed, Woolf did for the engines of Trevithick, Evans, and others, what Hornblower had done for those of Watt; he applied to them the principle of the double cylinder. As he could make use of high pressure, there was promise of success for the invention, and it did succeed, so that he has given his name to engines having two cylinders.

Woolf's patent was taken out in 1804. It contained, as has often been remarked, erroneous notions about the expansive power of steam.

The fact that contributed to the success of Woolf engines, was that although the expansion was not sufficient to yield much advantage over ordinary engines, the division of the work of the steam between the two pistons diminished the differences in pressure and the loss of steam. This was an important matter in the early constructions. Engines of this kind need little repair. We could mention two instances in an industrial centre in Normandy, of engines with two cylinders, which have been in action for nearly fifty years.

In 1805, Willis Earle took out a patent for engines composed of a large and small cylinder superposed, with two pistons mounted on the same rod, a device frequently repeated since that time.

The first Woolf engine was set up in a London brewery. Afterwards Hall made a large number. In 1815 they were introduced into France by Edwards, and they rapidly came into use, without much change in construction. Edwards' engine of 1817 differs hardly at all, even in details, from those that are to-day put up in some of the manufacturing towns. In 1820 the English engineers, Aitken and Steel, built engines with three cylinders, two small and one large. Notice of these engines appears in various works, especially in that of R. Stuart.

In 1824 Joseph Eve patented a compound engine, in which the steam, after acting in a high-pressure engine, passed into a low-pressure engine, where it acted expansively. He employed rotary engines. Here was the first idea of a mode of action different from that of Woolf's engines.

In 1834 Ernest Wolff (a German, we infer, from his name) took out a patent (No. 6,600) of an engine described as compound, as nowadays constructed, which indicates the possibility of modifying existing engines so as to adapt them to the new mode of action.

This patent is very interesting, and it is singular that English authorities hardly refer to it.

It is certain that compound engines with two cylinders and intermediate reservoir, to which the name of Woolf has been given, though they have not the same mode of action, should be called "Wolff engines."

We give the essential part of this patent. "The invention consists of the combination of two or more engines, each complete in all its parts, and so disposed that while the first receives steam at one, two or more atmospheres of pressure, the next engine is moved by the steam that escapes from the first. In the last engine the steam is condensed in the ordinary way, or escapes into the atmosphere. The work supplied by the several engines is applied to the same shaft, or to several combined, or to independent shafts.

"As in steam vessels and other applications, two conjoined engines are generally employed. The present invention is especially adapted for this purpose, as it presents economic advantages; as it reduces the expense of the apparatus without increasing its complication.

"It is sometimes useful to have between the cylinders an intermediate reservoir to regulate the pressure; this may be placed with advantage at the base of the chimney, so as to maintain or raise the temperature and the pressure of the steam in its passage from one cylinder to the other. Indeed, if necessary, the heat may be supplied by a special fire-box.

"It is often necessary to employ a special pipe with a stopcock to admit the steam from the boiler to an intermediate reservoir in order to give to the machine the power of starting any crank. This direct introduction may be employed to increase for a time the power of the engine."

The writer then explains a method of modifying old engines by adding to a high-pressure engine a low-pressure cylinder; or, in the case of a marine engine, by substituting for one of the low-pressure cylinders a high-pressure cylinder.

The drawing annexed to the patent shows a pair of marine beam-engines.

In 1837, William Gilman patented an engine consisting of two cylinders placed one on the other, one of them having an annular piston with a single cut-off, with multiple ports disconnecting the two cylinders. This disposition has been often reproduced, and is frequently employed nowadays, especially in Sweden. Gilman also describes an engine of three cylinders in which the steam acts in succession.

In 1837, Jonathan Dickson patented (No. 7,439) engines in which the steam acts successively by means of boilers with decreasing pressure, or parts of boilers constituting a compound boiler. This contrivance has also been made use of since the time of the invention. In fact, it is nothing more than Woolf's patent: for this proposes to re-heat the intermediate reservoir by a special fire-box, a process which constitutes in a certain way a low-pressure boiler.

Dickson proposes the use of feed-pumps to serve as guides to the piston cranks, and to control the slide-valves of each engine by the other engine.

In the same year James Slater patented (No. 7,467) engines acting in the same way, with an intermediate reservoir, employing a low-pressure boiler. He describes a regulating valve designed to keep the steam pressure at a fixed point, and also to start the engines. This is nothing more than Woolf's invention—the valve, perhaps, excepted.

The drawings annexed to the patent show various applications, especially a pair of marine beam-engines.

William Whitman, in 1839, patented an engine in which the piston has a sheath on one side only, so that the cylinder has two different capacities. The steam first acts in the annular space, then expands into the other portion of the cylinder. This disposition, applied with some success by the inventor, has been frequently reproduced. It is probably the simplest way of applying the Woolf method of action.

In 1841, James Sims patented an engine of two superposed cylinders, with pistons on the same rod; with this special distinction, that the bottom of the smaller piston is in constant communication with the top of the larger.

In 1842, Hinrik Zander took out a patent (No. 9,516) of an engine, in which the steam acts in the first cylinder expansively, to a certain extent, then passes into two others which are larger, and expands. The three cylinders are attached to the same shaft, so that their motion may be as uniform as possible. The low-pressure cylinders are provided with jackets which contain the steam from the boiler. Zander describes intermediate reservoirs, and proposes to introduce into them, or into a communicating pipe supplying their place, a float-valve to allow the escape of condensed water.

In his drawings is represented a disposition in which the crank of an oscillating high-pressure cylinder, placed obliquely, is attached to the crank of a marine beam engine. This engineer (probably of Holland) seems, according to documents which we have found, to have built some marine engines on this plan.

Octavius Henry Smith patented, in 1844,

an engine acting on the Woolfian principle, consisting of a high-pressure and a low-pressure cylinder, both oscillating and having their rods attached to the same crank. The Cricket Engine, referred to in Bramwell's memoir, is of this kind. A complete description will be found in the "Practical Mechanic and Engineer's Magazine," 1847. Afterwards, we find many patents of expansion engines. We mention only those of Perkins, 1844; McNaught, 1845, which modified old engines by the addition of a high-pressure cylinder; of Thomas Craddock, 1852; Daniel Adamson and Leonard Cooper, 1852, which superheated the steam in its passage from the high to the low-pressure cylinder, by means of tubes set in the smoke-box of a tubular boiler.

We shall not go further in our examination of these patents. It is perceived that, since 1852, all the essential elements of the action of steam by expansion, in separate cylinders, have been pointed out, and that there remains nothing to be invented, even in perfecting details. We shall look further back for applications.

The Cricket Engine was built in 1847, by Joyce & Co., of Greenwich. It exploded the the same year. Bramwell speaks of a boat built at about the same time by Spiller, in which was placed an engine, consisting of a low and high-pressure cylinder. We have found no document concerning it.

According to the authority of "Zeitschrift des Oster Ing. and Arch.," 1867, M. Roetgen of Rotterdam has built engines, since 1840, composed of cylinders inclined towards each other, and acting on the same pair of cranks, the same steam being successively used in the two cylinders. These engines were put into the boats Elizabeth, Stadt Magdeburgh, Kron-Prinz Paul Friedrich.

We do not regard the date 1840 as exact. If, as is probably the case, these engines are those made according to the plans of Zander, they were evidently built after his patent of 1842.

The journal "Engineering" of Sept. 9, 1870, contains a description and drawing of an engine built in 1848 by the Sterkerader Hütte for the Rhine boat Kron-Prinz von Preussen. This engine had two cylinders one $0^{m},508$ in diameter, and $0^{m},800$ long; the other $0^{m},914$ in diameter, and $0^{m},914$ in length. Each acted on a crank; the two cranks were connected so that the effect was the same as if the cylinders acted at right angles upon the cranks, while the angle between the axes was 130°. There was no special intermediate reservoir. The connecting-pipe $0^{m},254$ in diameter, acted in its stead. There were no steam jackets, and, as no precaution was taken to prevent the condensation of steam in its passage from one cylinder to the other, economical results could not be expected.

Still it is a fact that Feyenoord's works at Rotterdam, where these engines were first constructed, have never given them up. We ourselves saw at Rotterdam in 1860 a steamboat of 70 h. p. nominal, the Wilhelm II., which had served as a pleasure boat for the King of Holland. The engine, with low-pressure cylinder, had been modified by the addition of a high-pressure cylinder inclined to the other, acting on the same crank, the same steam working successively in the cylinders.

It would be unjust to omit mention of Carillon, a Paris builder, who succeeded (1842) in making a low-pressure engine work with the discharged steam of one at high pressure. This was set up at the St. Louis Glass Works. The essay seems not to have been repeated; being abandoned, we think, because of the failure of a surface condenser.

In 1852, James Samuel applied the principle of continuous expansion to locomotive engines. This consists of a simultaneous action of steam upon the two pistons. Suppose two pistons whose rods act at right angles to the crank. The steam works at full pressure during half the stroke of the first. At this moment admission ceases, and the first cylinder is put into communication with the second while its piston is at the beginning of its stroke. Expansion occurs simultaneously in the two cylinders until near the end of the stroke of the first, then in the second, only till nearly the end of its stroke.

This system, related to that of Milner, mentioned in Bramwell's memoir, has been again taken up by Stewart & Nicholson, and applied in the tugs on the Thames. Though simple, it has the disadvantage of not avoiding great depression of temperature as well as those of Woolf & Wolff, since the two cylinders communicate with the discharge ports or the condenser.

The experiments of Samuel, reported in the "Memoirs of the Institution of Mechanical Engineers," 1852, were made on a freight and a passenger engine on the Eastern Counties Railway. In the first there were two equal cylinders; in the second the larger cylinder had a section twice as large as that of the smaller. Though the results seemed quite favorable, the essays were abandoned until the time when they were again resumed by Stewart & Nicholson. This is inferior to the other kinds of compound engine.

The first noted applications of double-cylinder engines were made at Glasgow, in 1856, by Randolph & Elder. A little after, Rowan & Horton constructed three cylinder engines; one high-pressure feeding two others. There were 6 cylinders in the machine. The steam was supplied at a pressure of 8 atmospheres by boilers of a special form.

One of these engines, according to Rankine, should not consume more than 0,500 k. of fuel per horse power hourly. This would seem doubtful; but it would be useless to discuss the point, for the engines have not stood the test of service. The boilers are rapidly destroyed, and the construction is too complicated. The condensers were surface condensers of a particular pattern.

Rowan & Horton put one of their engines into L'Actif, a French vessel.

In 1859, Humphreys & Tennant, of Deptford, built for the Peninsular and Oriental Company Woolf engines with moderate tensions. These engines, set up in the steamers Poonah, Mooltan, Carnatic, Baroda, Delhi, etc., at first gave good results. The pressure was 25 lbs., with surface condensation. The cylinders of the Mooltan were 96 and 46 in. in diameter, with a length of 3 ft. Consumption was 2½ lbs. per horse power. The good results were not permanent, especially in matters of detail.

All these have been replaced by single engines built by Humphreys & Tennant.

In 1861, Normand changed to the Wolff the engine of the small steamer Le Furet built by Penn. The engine worked at 6 atmospheres with intermediate reservoir, re-heating, and *monhydric* condensation. The results were excellent. Afterwards Normand altered in the same way the engines of the Eclair, the Albert, etc., and still constructs the same kind of engines

The Imperial Marine made essays moderately successful with three cylinders. The expansion was not great enough, the cylinders being of the same diameter, so that the economic advantage was not important.

But the principle seems natural, and the English Admiralty is at present changing the engines of the ship Jumna.

Escher, Wyss & Co., of Zurich, have built, from the plans of their engineer, Murray Jackson, marine engines with a low and a high-pressure cylinder, set side by side and acting perpendicularly to the cranks. One of these engines was exhibited at Paris in 1861, but it was out of sight under a shed. They have no special intermediate reservoir, the connecting pipe of the cylinders acting in its place. This firm have constructed a large number for the Swiss and Italian lakes, for the Danube, Rhine, and other rivers. Their engines are of the Woolf system. One with four cylinders was exhibited at London in 1862; it is now upon a boat upon Lake Lucerne.

The compound marine Wolff engine is at present built in many English shops; though some maintain the Woolf type, with superposed cylinders. In France all engines are of the first kind.

II. We now consider the method of action in compound engines, beginning with those of Woolf.

In this system the pistons almost always move parallel and in the same direction, although engines with opposing cranks have been constructed (Randolph & Elder; Bondier Frères, of Rouen; Carret, Marshall & Co.) in order to have more direct connection between the cylinders. We suppose that the cylinders have the same length.

The steam acts directly upon the first piston, then expansively; and when the small piston is at the end of its stroke, the connection with the large begins, so that the space under the action of steam at any instant is composed of a fraction of each cylinder, the fractions having an inverse ratio.

We calculate the volume for each period of the stroke, and find the corresponding pressure by Mariotte's law. Let S and s represent the areas of the pistons, l the stroke when the pistons are at a distance z from the beginning of the stroke. The remaining volume in the small cylinder is $s(l\text{-}z)$, the volume of steam in the large cylinder is Sz, hence the total volume occupied by the steam is

$$s\,(l-z)+\mathrm{S}\,z$$

or

$$s\,l-s\,z+\mathrm{S}z=s\,l+(\mathrm{S}-s)\,z.$$

If P′ is the pressure at the end of the

stroke of the small piston, the pressure at any point between the two pistons is

$$X = \frac{P' s l}{s l + (S - s) z}.$$

By giving to z a number of values, the curve of expansion may be constructed.

P' is the boiler pressure if there is no expansion in the small cylinder; otherwise, from P' we deduct P' from the pressure P in the boiler by the relation

$$P' = P . \frac{l}{l n}.$$

n being the expansion in the first cylinder. Denoting by v and V the volumes of the cylinders, by m the total expansion, we have for the expenditure of steam

$$q = \frac{V}{n}.$$

The work of the volume q of steam is

$$T = q P\left((1 + 2{,}3026 \log. \frac{V}{q} \right)$$

an expression which does not contain v, *i. e.*, the work does not depend on the volume of the small cylinder, but only on the volume q of steam expended, and upon the dimensions of the large cylinder and the initial pressure.

Theoretically, then, the work is the same as if there were no small cylinder, and the volume of steam introduced into it is directly expended in the large cylinder. Should we therefore conclude, as most persons do, that the small piston does no work, and that it is merely a distributor? This would be utterly erroneous; the work of the low-pressure cylinder alone, would be represented by V and by a certain mean pressure π. Then denoting by p the mean pressure in the small cylinder, by p' the mean pressure between the two pistons, we have

$$T = v p - v p' + V p.$$
$$= p v + p' (V - v) = V \pi.$$
$$\therefore \pi = p' + \frac{v}{V} (p - p'),$$

a value always larger than p'; hence the total work is always greater than that of the large cylinder.

From the expression $m = \frac{V}{v} n$ we have $\frac{V}{v} = \frac{m}{n}$, which determines the proportion between the cylinders for a given total expansion and introduction into the first cylinder.

We observe that in order to have $V = v$, or equal cylinders, we must have $n = m$; and the second cylinder would be useless, so that the two cylinders could be practically equal in Woolf's engine. The same is true in the Wolff engine, as will appear.

The following table shows the dimensions of the large cylinder (those of the small being equal to unity) for given total expansions and admissions into the small cylinder:

Admissions to the small cylinder.	0.3.	0.4.	0.5.	0.6.	0.7.	0 8.	0.9.
Total expansion 5....	1.5	2	2.5	3	3.5	4	4.5
10....	3	4	5	6	7.	8	9
15....	4.5	6	7 5	9	10.5	12	13.5
20....	6	8	10.	10	14.	16	18

The ratio 5 is not exceeded in practice; it being better, for large expansions, to increase the expansion for the first cylinder.

We have so far supposed that there was no dead space, a condition never realized. This space is composed of two parts; one, the space between the small piston and the bottom of the cylinder at the end of its stroke and the port of the small cylinder, the other composed of the interior capacity of the small slide valve, of the connecting pipe between the valve boxes (we suppose each cylinder has its special distributor), of the valve box of the large cylinder, of the port of the large cylinder, and finally of the free space between the large piston and the bottom of the cylinder at the end of its stroke.

The first space contains, at the end of the stroke, an amount of steam (P′) of the final tension of the stroke of the small piston; but the second space contains steam of a tension (P″) corresponding to that existing at the end of the stroke of the large piston; and it should be filled with steam of the tension P′.

A communication is established between the two cylinders; the tension diminishes because of the dead space not corresponding to the displacement of the pistons; and the mean pressure on the large piston is considerably diminished.

In the old two-cylinder engines the dead space is considerable, sometimes exceeding one-third the volume of the small cylinder; but it has been diminished by a suitable disposition of slide-valves; and it can be prevented in a certain measure by causing *compression* at the end of the stroke of the large piston.

If the dead space is a fraction $\frac{1}{k}$ of the volume v of the small cylinder, the pressure at the beginning of the stroke of the large piston, instead of being $\frac{1}{k}$ will be $\frac{1}{V + \frac{v}{k}}$. For example, for $k = 3$, it would be

$$\frac{1}{1.33} = 0.75,$$

instead of 1.

If the initial pressure in the large cylinder, instead of P′ is $\frac{P' v}{v + \frac{v}{k}}$, at the end of its stroke, when the volume is $V + \frac{v}{k}$, the final tension will be

$$\frac{P' v}{v + \frac{v}{k}} + \frac{v + \frac{v}{k}}{V + \frac{v}{k}} = \frac{P' v}{V + \frac{v}{k}}$$

instead of $\frac{P' v}{V}$. The ratio of the two volumes is $\frac{1}{1 + \frac{v}{V k}}$. If $\frac{v}{V} = 0.2$ and $k = 3$, the ratio is 0.98.

The final tension is not sensibly modified because the ratio of the volume of the cylinders diminishes the effect of the dead space; that is, because the steam contained in this dead space expands during the stroke and tends to restore the tension.

For a better understanding of the subject, and to show the action of the engines, we reproduce in Figs. 1 and 2 the diagrams of indicator of a large Woolf beam engine, built by Slawecki, an engineer at Rouen, who subjected the engine to interesting dynamometric experiments.

Fig. 1.

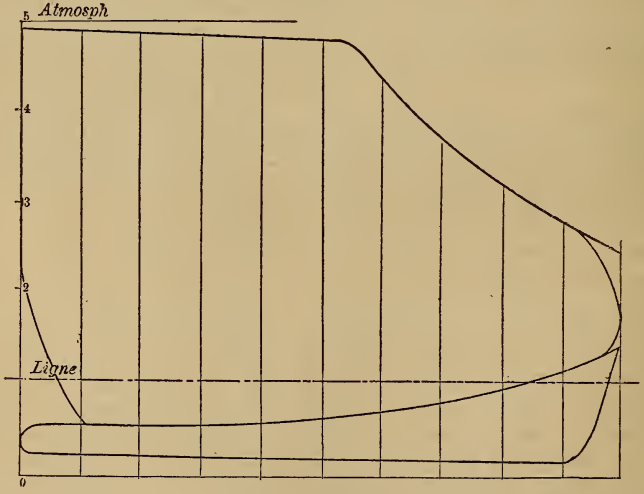


Fig. 1 shows the curves of the two cylinders to the same scale and with the same atmospheric line. We observe that the counter-pressure of the small cylinder corresponds very exactly to the pressure upon the large piston, showing that the resistances in the passages between the two cylinders are so diminished as to be almost insensible.

That the two curves coincide at one point, is due to the fact that they were taken at the top of the cylinder, where the real representation of the action of the *same* steam upon each piston is not given.

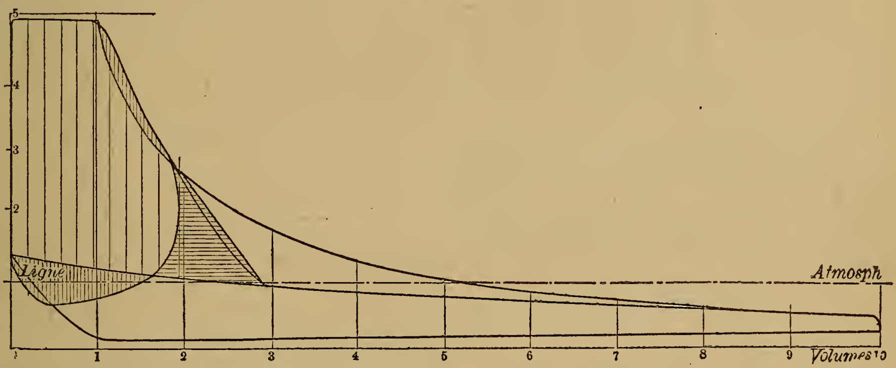
The effect of dead space is shown by the difference between the final pressure in the small cylinder and the initial pressure in the large. In this case the difference is one and a half atmospheres.

In order to compare the action of the Woolf with that of an ordinary engine with a single cylinder, we show in Fig. 2 two curves to the same vertical scale for ordinary pressures, but with abscissas to scales proportional to the volumes of the cylinders. As the two areas coincide upon the portion marked with vertical hatchings, this portion has been transferred to an equal area hatched horizontally. The curve of work of the steam acting on a single cylinder with the same expansion as in the engine with two cylinders is given; and the small portion of the area corresponding to the work of the small cylinder beyond curve is shown within it.

It is seen that the final pressure is exactly the same in the two systems, except that there is a defect of area of work in Woolf's engine corresponding to the loss due to dead space. Calculating the area of this portion, we find the loss due to the use of two cylinders to be nearly 15 per cent.

The majority of authorities rest here, and take this result as a text for condemning the compound-engine, at least in principle. We shall see that the *physical* loss in the action of expansive engines with one cylinder far surpasses that of the Woolf, a loss in some sort apparent, and depending upon a simply geometric cause.

Fig. 2.



This would be the place to examine the causes of the superiority of this engine due to expansion; but as this superiority is common, in theory at least, to all double-cylinder engines, we shall consider the question after an examination of the second kind of engines.

We close with this remark concerning Woolf engines: if each cylinder is provided with a special distribution, it is not necessary that there should be a mathematical correspondence of exhaust port of the first cylinder with the admission port of the second. The existence of dead spaces permits separation by a certain interval; while near the dead-points the angular displacement of the crank corresponds to a very small linear displacement of the piston. Hence if each cylinder acts upon a special crank, the two cranks may be set at an angle of 45 deg. to 135 deg., acccording as the pistons are to move in the same or opposite directions. This disposition which facilitates the passage of the dead-points is sometimes employed, as appears in Bramwell's memoir.

III. In the second system of engines, which should be called Wolff engines, the second cylinder is not supplied directly by the first, but by an intermediate reservoir of such dimensions that the pressure within it may be regarded as nearly constant, being in some sort an engine with graduated pressure.

Denoting by P the pressure in the boiler, supposed equal to pressure upon entering the first cylinder, and by P′ the pressure in the intermediate reservoir, due in the first place to direct introduction of the steam from the boiler, and controlled by a safety valve; by P″ the resisting pressure at the discharge port or at the condenser; then, if the expansion n in the first cylinder is such that the final pressure in this cylinder is P′, or differs from it but little (v being the volume of the small cylinder, and q the volume of the steam admitted), we have

$$\frac{P'}{P} = \frac{q}{v} = \frac{1}{n}.$$

The second cylinder receives all the steam from the boiler at the pressure P″.

Then $\frac{V}{q} = \frac{P}{P'} = m$; m being the total expansion, hence $\frac{V}{v} = \frac{m}{n}$, and the ratio of the volumes of the cylinders is the same as in the first system. But the large cylinder, instead of receiving the steam during the entire stroke, receives it only while a fraction equal to the expansion n' corresponds to the decrease of the pressure from

P′ to P″; $\frac{\text{P}'}{\text{P}''} = n$ and since $\frac{\text{P}}{\text{P}'} = n$ and $\frac{\text{P}'}{\text{P}''} = n'$, $\frac{\text{P}}{\text{P}''} = n\,n' = m$.
The total expansion is equal to the product of the partial expansions, and the expansion in the second cylinder is equal to the ratio of the volumes of the two cylinders. We see that if one should make the two cylinders equal in an engine of this kind, there would be no expansion in the second cylinder. The engine might act if there were a notable difference between P′ and P″, but the whole possible expansion would not be utilized, and the system would have no *raison d'être*.

One of the advantages of this arrangement is that the dead spaces are not hurtful, as they are actually utilized by enlarging them.

The work of the steam in the first cylinder is

$$\text{T} = q\,.\,\text{P}\left(1 + e\log\frac{\text{V}}{q}\right) - \text{P}'\,v.$$

that in the second is

$$\text{T} = q'\,\text{P}'\left(1 + \log\frac{\text{V}}{q'}\right) - \text{P}''\,\text{V}.$$

Taking the sum for the total work, and substituting

$$q = \frac{\text{V}}{m},\; q' = \text{V}\frac{n}{m},\; p' = \frac{\text{P}}{n},$$

we have

$$\text{T} = \frac{\text{V}}{m}\left(\text{P}\,(1 + e\log n - 1 + 1 + e\log\frac{m}{n}\right) - \text{P}''m),$$

$$\text{T} = \frac{\text{V}}{m}\text{P}\,(1 + e\log m) - \text{P}''\,m$$

$$= \frac{\text{V}}{m}\text{P}\,(1 + e\log m) - \text{V}\,\text{P}''$$

$$= q\,\text{P}\left(1 + e\log\frac{\text{V}}{q}\right) - \text{V}\,\text{P}''.$$

This expression represents the work in the large cylinder of the quantity of steam at tension P, expanded from volume q to the volume V.

The principle stated concerning Woolf's engine also holds as to the action of this kind; that is, the work is the same as if the large cylinder were the only one, and the steam admitted to the small cylinder were directly introduced into the large, and expanded in the ratio of the total expansion.

In this kind of engine the work of the two cylinders is regulated as much as possible. Equating the expressions of work given above, we find after proper substitutions

$$v\left(\frac{\text{P}(1 + e\log n)}{n} - \text{P}_{\prime}\right) = \text{V}\left(\frac{n}{m}\text{P}'\,(1 + e\log\frac{m}{n}\right) - \text{P}''),$$

and substituting for P′ its value $\frac{\text{P}}{n}$,

$$\frac{\text{V}}{v} = \frac{\frac{\text{P}\,(1 + e\log n) - \text{P}}{n}}{\frac{\text{P}}{m}\,(1 + e\log\frac{m}{n}) - \text{P}''} = \frac{\frac{\text{P}}{n}\;e\log n}{\frac{\text{P}}{m}(1 + e\log n') - \text{P}''}$$

This expression gives the ratio $\frac{\text{V}}{v}$ for known expansions n and n', for we always have $m = n\,n'$.

Remembering that

$$\frac{\text{P}}{n} = \text{P}' \text{ and } \frac{\text{P}}{m} = \text{P}''$$

we have

$$\frac{\text{V}}{v} = \frac{\text{P}'\;e\log n}{\text{P}''\;e\log n'} = n'\,\frac{\log n}{n'}$$

and for $n = n'$

$$\frac{\text{V}}{v} = n$$

a relation already known.

In Woolf's engine the extreme difference of temperatures in the small cylinder is larger than in the engine with intermediate reservoir. Here is a theoretic inferiority, at least for engines of slow action in which the decrease of temperature due to the diminution of tension is noteworthy. Hence, as we shall see, the use of an envelope of steam is in this case more necessary.

If the engine with reservoir has a real advantage over that of Woolf, it has, on the other hand, the inconvenience of requiring for considerable expansions, that the admission be early cut off in each cylinder: since for a total expansion of 10 volumes the expansion should occupy $\frac{1}{5}$ in one cylinder, $\frac{1}{2}$ in the other, or $\frac{1}{3.16}$ in each, if expansions in both are equal; and we know that ordinary distribution does not favor small introductions.

Generally a fixed expansion is imposed upon the large cylinder; and the small cylinder is provided with a special apparatus, with variable cut-off to reduce admission as desired. It is difficult, however, to effect large expansions, and too great expansion in the large cylinder produces some of the disadvantages of the single cylinder. It would be better, in this case, to employ multiple expansions and several successive cylinders, as has often been proposed.

(To be continued.)

THE POLA BASIN, DOCK AND RAILWAYS.*

By HAMILTON E. TOWLE, C. E.

Extract from the Minutes of the Proceedings of the Institution of Civil Engineers (London)

About the time that it became evident that the Austrian Government must eventually abandon the port of Venice as a naval station, the harbor of Pola was selected by a commission of Engineers and naval officers as a suitable one to which to transfer its materiel, and at which future permanent works to complete a capacious arsenal and dockyards should be constructed. Pola is situated directly south of Trieste, on the western coast of the peninsula of Istria, south-west of Fiume, and about 60 miles distant from both those ports. Venice, on the other side of the Adriatic Sea, is 80 miles distant in a north-westerly direction. The harbor of Pola is a circular bay, connected by a narrow and short outlet with the Adriatic. It is particularly favorable for the purposes of a naval station, having ample room, good anchorage, and complete natural protection.

The Austrian Government abandoned the idea of constructing excavated docks, in consequence of the difficulties experienced in making the necessary cavities in which to build the works, from the percolation of the sea water through fissures in the volcanic rock; and they determined on the American Floating Dock, Basin, and Railway system. The floating dock adopted was that known as the Balance Floating Dock (Gilbert's System); and the basin and railways were in general principle the same as those constructed at the United States Navy Yards at Portsmouth, New Hampshire, and at Pensacola, Florida. These were the first dock basins with railways that had been constructed; they were contracted for in the year 1848, and active operations were commenced a few months later.

The function of a basin for a floating dock is to supply a place in which the dock itself may be grounded, either with a vessel upon it to undergo extensive and prolonged repairs, or to enable the vessel to be hauled out of the floating dock upon the railways; which latter operation is only required in cases where vessels are moved from the dock to land above the sea-level, or the reverse. Another use to which the basin may be put, should occasion require it, is to provide a convenient means of obtaining access to every part of the usually submerged portion of the floating dock itself, either for examination or repair. A basin to fulfil these requirements must be so constructed as to permit the dock, with or without a vessel upon it, to be floated into it, and the entrance passage to be closed by means of gates or caissons. Where the tidal rise and fall are not greater than the entire depth of the water in the basin at high tide, suitable pumping machinery must be erected.

Calculations, based upon the maximum draught, etc., of the floating-dock, determined the depth and requisite area of the basin at Pola. These dimensions were as follows:—

Width inside the enclosing walls...	$211\frac{56}{100}$ ft.
Length " " "	$311\frac{50}{100}$ "
Depth from the top of the enclosing walls to the top of the stringers (for receiving the dock when grounded)	17 ft. $1\frac{1}{4}$ in.
Depth from the level of ordinary high water to the top of the stringers..	13 ft.
Depth from the level of ordinary low water to the top of the stringers..	11 "
At the highest flood tide the depth above the top of the stringers was	$14\frac{1}{2}$ "
At the lowest ebb tide the depth above the top of the stringers was	$9\frac{1}{2}$ "

The maximum difference in the hydrostatic head, inside and outside the basin, during the progress of the works, was 20 ft.

The Austrian Government preferred that the basin and railways should, if possible, be constructed at an island (called Scoglio d'Olivie) centrally situated in the harbor, and from which several vessels had already been built and launched. Having mainly in view the treacherous and honeycombed character of the rock forming the harbor, it was decided to build a foundation upon the natural bottom of the bay at the place selected. The first operation consisted in a careful survey and contouring of both the upper and the lower surfaces of the mud bottom, the mud resting upon rock below; and to the care taken in this preliminary survey, the Author attributes much of the success in mastering the

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* "An Account of the Basin, the Balance Dock, and the Marine Railways, at the Austrian Naval Station at Pola, on the Adriatic." By Hamilton Ela Towle, of New York, U. S. A.

difficulties which arose as the work progressed. The mud varied from 2 ft. to 12 ft. in thickness. As the rock was unfitted for holding, or even for receiving, sheet-piles, except when they might happen to strike a fissure, it was decided not to use the ordinary clay-puddle cofferdam.

It was observed that at Trieste, Fiume, and Pola, as well as at other Austrian ports, wharves and moles had been successfully constructed of a sort of concrete, bearing the name of Santorin béton; and, as these works had been found durable and permanent in exposed situations, it was determined to adopt this material, as it could be obtained at a reasonable cost, while the expense and risk attending the temporary use and final removal of an ordinary dam would be avoided. The largest blocks of Santorin béton were found in the mole at Fiume. They were 25 ft. in vertical depth, and 22 ft. wide at the top, at the level of low water, battering towards the bottom at the rate of 1 in 4 or 1 in 6. They rested upon loose rubble stone, consisting of ordinary quarry rubbish, deposited on a level bed along the line of the mole for a thickness of several feet. The length of these béton blocks was 50 ft.; and they had been thus formed *in situ.* Plank caissons were built on shore, and were securely tied together, and then launched and floated over the spot selected. They were next loaded and sunk upon the previously-prepared bed of rubble, and the béton was deposited within them. When it had become sufficiently indurated, the planking was removed, excepting 21 cross timbers forming ties to the sides of the caisson, which were left embedded in each block, or section of the wall.

After definitely deciding that Santorin béton should form the substructure of the enclosing basin, and at the same time serve the auxiliary purposes of the ordinary cofferdam, it appeared that to excavate a continuous trench for the walls, to allow them to rest upon the clear surface of the rock under the mud, would involve the construction of special machinery for the greatest depths, and, after all, only secure a solid bottom at great expense, which eventually would have to sustain the weight of the walls themselves when finished. A water-tight joint seemed the one thing most required at the junction of the enclosing wall, or dam, with the bottom, for there could be no leakage or percolation through the body of the béton wall, as long as the material was not cracked by unequal settlements or strains. But the Author assumed that accidents would occur, and that they would, if not effectually provided for, prove troublesome and dangerous.

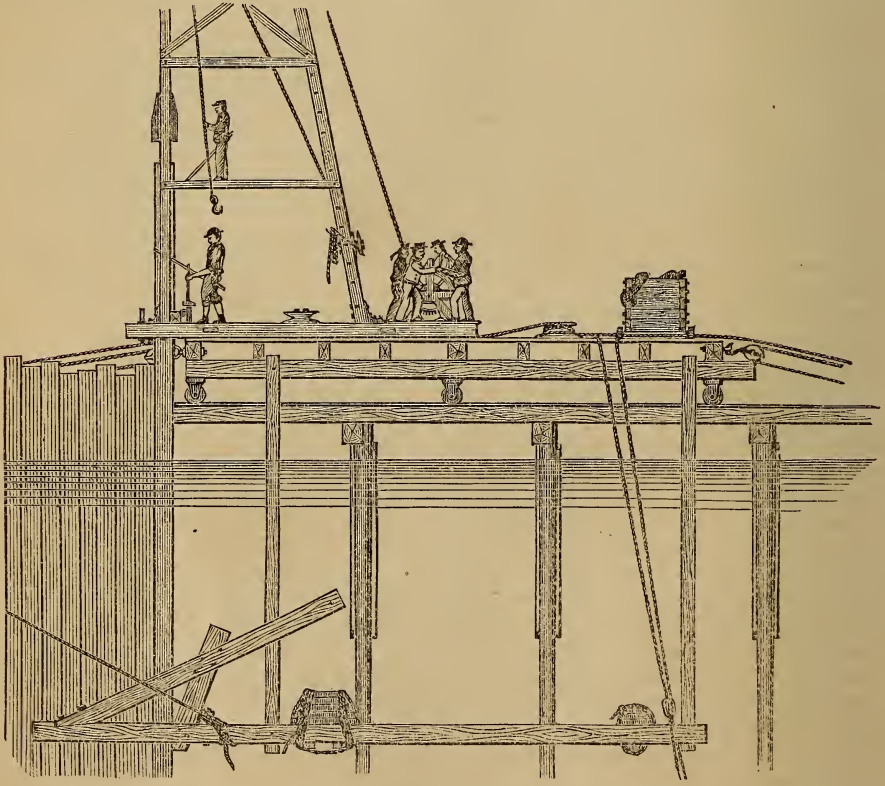
Many cross-sections of walls were considered; but finally it appeared that a wall of a plain rectangular section presented the greatest advantages and the least objections. In calculating the minimum thickness of walls admissible, regard was paid to the fact that the site of the basin was a greasy mud bottom, dipping towards deep water at an angle of from 2 deg. to 10 deg., and therefore rendering a slip of the basin possible. Cracks and fissures were provided against by joints across the walls, at intervals of from 40 ft. to 90 ft., thereby forming weak places, which being selected with respect to the irregularities of the bottom, the rock protuberances and depressions, the thickness of mud, etc., rendered the location of cracks almost a certainty. Experiments were made to ascertain the sustaining power of the mud bottom when subjected to a pressure somewhat greater than would be brought upon it from the walls and their occasional loads; and this was not found to differ much even in places where the mud varied in depth several feet. In the application of this experimental information, the prominent projections and marked depressions in the rock were found to be distant from each other not less than twice the vertical height of the wall, and this distance was assumed as the proper limit for the length of the superimposed béton blocks, as it had been previously ascertained, by experiment, that the strength of Santorin béton was ample to resist transverse fracture, if the blocks did not overhang the point of support for a greater length than their own thickness. Having determined the probable difference in the compression of the mud at the prominent projections and marked depressions, and knowing the distances of these points apart, and the vertical depth of the two blocks above, the size of the crack, or opening, that would take place between them became a known quantity. Now, if the mud above a depression were compressed 12 in. more than the mud at contiguous projections, and the length of each block were three times its depth, it was clear that the opening between the two blocks would be 4 in. at the widest part, and gradually diminish to zero at the upper surface. It was found, by this method of calculation that no crack would be likely to exceed 6 in. in its widest part, with vertical butt joints between the adjacent blocks of béton, and the ends of the blocks marked the localities where the cracks would certainly be found. To check the passage of water through the wall, and to connect the adjoining ends of contiguous blocks of béton so as to prevent them moving upon each other laterally, a rectangular post, 18 in. by 24 in., was inserted vertically in each of the joints, reaching from the upper surface of the blocks, through the mud, to the rock bottom below. The post projected 12 in. into each block of béton. These posts received the name of "coags," and were made of two sticks of timber, 12 in. by 12 in., squared up and bolted together until the the proper length was obtained. After smoothing off one of the sides, cross planking, 6 in. thick, was well secured by bolts and treenails, and the joints between the timbers and planking were well caulked. The largest coag joint opening was 5½ in., after all apparent settlement ceased, and the "coags" were found to fulfil all their intended purposes.

A brief description of the manner of constructing the sheet-piling work or caissons, in which the blocks were formed, will now be given. A few round piles were first driven, by hand and steam pile-driving machines, from suitable floats, to which to secure mooring and hauling lines; then the side walls of the basin were staked out, by driving, 10 ft. apart, two, and in most cases three rows of round piles within the space to be occupied by the Santorin walls. The greatest care was taken to make the stage piles stand vertically, as they were to remain permanently in the walls, as well as parallel to each other, so as to permit the free movement of the béton in settling. Straight, tapering round piles were chosen for this part of the work. Cross caps, of 12 in. sawn timber, were screwed to the heads of the stage piles, and upon them, at their outer ends, longitudinal stringers, 12 in. by 12 in., were securely bolted, the outer sides of which defined the inner and outer faces of the Santorin wall. The staging was strengthened by vertical diagonal bracing, secured to the piles, and by horizontal diagonal bracing secured to the tops of the cross caps. The vertical bracing was removed during the process of filling the caissons, as it was no longer required, the béton affording sufficient support. The greater part of sheet-piling was of soft Italian, Styrian, and Austrian timber, 12 in. thick. Every piece was made quite straight upon the sides adjacent to, or in contact with, contiguous piles, and the piles were driven by ordinary pile-driving machines mounted upon travelling platforms, provided with double-flanged wheels resting upon iron rails, which in turn were supported upon the tops of the longitudinal stringers. To the outer side of these longitudinal stringers the upper ends of the sheet piles were secured as fast as they were driven.

As it was desirable to render the face of the béton wall uniformly smooth, it became a matter of importance to drive the sheet-piling accurately and evenly, a process which the depth of the water, the light specific gravity of the timber, and the character of the bottom, rendered somewhat difficult. To obviate this, the Author devised a machine, which for want of a better term was called a "Spider," and several of them were made and used about the work. It may be described as follows: (See Fig. 1, page 308.)

Two sticks of tapering timber are formed, by sawing a log 35 ft. long and 12 in. square, so that the larger ends are 8 in. by 12 in., and the smaller ends about 4 in. by 12 in. These are placed side by side horizontally, with the larger ends in the same direction, and spaced 12 in. apart, and parallel to each other, to form the side pieces. At about 8 ft. from the thicker ends is fitted a block of solid oak, 30 in. thick and about 6 ft. in length. A width of 9 in. on either side of the lower end of the block is cut away, to leave a thickness of 12 in. in the central part, which is made to project down between the parallel side pieces, and the three are securely bolted together. From its upper end, which is about 5 ft. above the side pieces, the oak piece slopes toward the thicker ends, at an angle with the vertical of 30 deg., and is formed into a sort of throat, to receive the ends of the piles. Two inclined side pieces, or cheeks, of timber, 8 in. by 12 in., and 17 ft. long, are secured, one on each side of the oak throat-piece, near the top, and, running down, rest upon the top of the long tapering side timbers near their thicker ends, to which they are securely bolted, as well as through the throat-piece and through each other. The side checks and oak block now form a funnel to receive the point of a pile, and to guide it through the 12-in. opening below. Two vertical timbers, called "hangers," 8 in. by 12 in., and about 20 ft. in length, are inserted between the side pieces, in the rear of the oak block, and about 20 ft. apart. They are each hinged at their lower ends, by stout iron bolts passing through both the side pieces and the vertical hangers. The side pieces at the rear are clamped firmly together with a distance piece between them 12 in. thick. Two ordinary tackle blocks, for receiving lateral guys, are now attached to the smaller ends of the side pieces, one on either side, and the guy ropes are rove through the blocks; a 9-in. hawser being made fast to the side pieces near the oak block. The apparatus is next weighted with ballast iron, laid across the side pieces until it will sink promptly, and it is now ready for use. Suppose a few sheet piles to be already driven, and the pile-driving machine to be in proper position to drive another pile in the line, the "Spider" is then advanced so that the two side pieces or horns of the machine are made to pass, one on either side, and clasp the sheet piles already driven; the hawser is drawn taut until the oak throat-block presses hard against the pile last driven, and the lateral side guys, properly secured, are drawn up by the men on the platform, until the machine below is in proper line, which is readily known if the hangers are vertical. All being now adjusted, a sheet pile is raised in the piling machine, and is readily driven in line with those already down. The throat of the "Spider" guides the point and body of the pile to its place, and the elasticity of the hawser permits a pile or two to pass through before slacking. In the result, the control of the work was so perfect, that the sheeting required, at intervals of from 20 ft. to 30 ft., a special wedge-formed pile to be driven butt down, to

Fig. 1.



"SPIDER" FOR FACILITATING THE DRIVING OF PILES IN DEEPWATER.

keep the work vertical at the driving point. With a "Spider" at least double the quantity of sheet piles can be driven per day in deep water, when the mud is shallow, than is possible at the same expense without such a contrivance, and the work is much better done. Between the surfaces of contiguous sheet piles was a single thread of ordinary spun-yarn ormarlin, which was tacked at each end of the piles before driving. This made the joints almost water-tight, as was proved by the fact that water was often found 2 ft. higher inside than outside the enclosed space.

The sides of the enclosure for one block having been completed, and the "coags" and cross-dams having been put in, the section was bolted together by ties above the level of the béton work. Fifteen of these blocks, or sections, were formed in the entire length of the enclosing walls of the basin, one-half the number being more than 80 ft. in length. At one point the béton wall is 35 ft. high, and the finished wall 7½ (Vienna) ft. higher; making the finished work slightly exceed 42½ ft. in height by 20 ft. in thickness.

The thickness of the walls varied from 15 ft. to 20 ft. and 26 ft. It was decided to make the entrance for admitting the dock on the eastern side of the north end of the basin, and to adapt it for receiving an iron caisson to close it. This opening was 120 ft. wide between the vertical walls, 128 ft. wide at the top line of the caisson, and the caisson measured 122 ft. along the bottom of the keel, each end having a batter of 3 ft. in the entire height of the caisson. The method adopted in constructing the enclosing sheet-piling for the other parts of the work was slightly modified, to meet the requirements of the masonry for the caisson at this point, as well as at the south-west corner, where the pump-well was located.

Santorin béton is composed of Santorin earth—a volcanic product from the Greek island of Santorino—and common lime paste, in the proportion of 7 cubic ft. of the former to 2 cubic ft. of the latter, forming the hydraulic mortar; and to this is added 7 cubic ft. of broken stone of the size usually employed in making concrete. The whole yields a batch containing 9 cubic ft., is made into a conical heap, and tempered by open air exposure for a period varying from one day to three days, when the heaps are ready to be used under water. Block No. 13, for example, required above 2,300 cubic yards, or 6,185 pastoni (heaps) of the prepared béton, and employed 82 men constantly for 18 days to prepare the béton and put it into its place. The cross-dams at the ends of the sections were safely removed in from 2 to 3 weeks after the last béton had been deposited, when the filling of the adjoining section could be commenced. The average time of filling the sections was 2 weeks.

After the bèton walls had been completed, the tie-bolts clamping the sheet piles against the sides of the blocks were gradually loosened, to enable the former to settle freely, and to compress the water from the mud below. Simultaneously, the interior rubble wall was built upon the top of the béton to a level above high water, so as to serve as a dam; and as this was finished, the material required for the superstructure of the walls was piled loosely upon the work already done, to cause the walls to complete their settlement while yet in motion.

The principal internal filling of the basin and the external sloping embankment against the sheet-piling having been proceeded with as the previous work progressed, as well as a temporary clay-puddle cofferdam, closing the intended opening for the iron caisson, pumping machinery was erected, and on the 2d of February, 1859, the operation of emptying the basin was commenced.

In consequence of heavy winds and a maximum rise and fall of the tide, the walls were, during the pumping out of the basin, subjected to a severe test; added to which, the water was removed from the inside of the basin to a greater depth than would occur again in its use. A slight lateral motion of the walls took place along the middle parts of the sides, by the opening of the vertical abutting joints of the sections upon the inner faces of the wall; but only one crack in the béton walls occurred worthy of mention, and this gave considerable trouble for several weeks. It was nearly vertical, and extended entirely through the pump-well wall to the re-entering angle on the outside. It made its appearance during the first twelve hours' pumping, and gradually increased in size until, upon the upper surface of the finished wall, the joints opened 3 in. At the bottom of the wall, upon the inside of the pump-well, there was no visible opening or crack. The separating parts slightly rotated upon a ridge or ledge of rock directly below, the greater part of the opening being caused by the sinking of the corner against which no supporting embankment had been made. After all the "coag" joints and the pump-well crack had ceased to increase in size, they were carefully cleaned out and walled-up with masonry to the depth of 1 ft. from the face of the wall; and metallic tubes or pipes were inserted through the wall for conveying away any slight leakage that might escape, without washing away the fresh mortar. Where a crack or joint appeared open on the external side of the béton walls, a pad, secured to a plank or timber, was firmly braced against it, until sufficiently tight to prevent the escape of fine mortar or pure hydraulic cement. These openings or fissures were then filled with thin grout, injected through a tube under a head of about 10 ft. above the wall, until the work was solid throughout.

The water having been exhausted from the enclosure to a depth sufficient to lay bare the earthy material previously filled in at the proper level, the work of constructing the bottom of the basin was prosecuted as rapidly as possible. This bottom consisted of thirty rows of foundation piles, capped with timber 1 ft. square, embedded in béton from 6 in. below their lower surfaces to the level of their upper sides. Upon the caps was secured a platform of timber, 6 in. in thickness, upon which was laid the masonry, forming and completing nine lines of stone stringers, to receive the bottom of the dock when grounded. The stringers varied from 8 ft. to 12 ft. in width; and between them the finished bottom of the basin consisted of a floor of Santorin béton, 1 ft. thick, on a layer of broken stone resting on the earth filling below.

The abutments, at either end of the caisson at the entrance of the basin, were built of solid masonry, well tied and bonded together. The floor or apron between the abutments was constructed of stone resting directly upon the béton wall at that part of the work, and when finished resembled in general appearance the entrance to an ordinary stone dock. The masonry superstructure, for the enclosing walls of the basin, consisted of three outside and three inside courses of headers and stretchers, having a uniform rise of 2 ft. 6 in., with a backing of common rubble masonry, the top of which was covered by flagging 9 in. thick. All the cut stone was Istrian marble, obtained from the neighboring islands.

The space of several hundred feet between the southern end of the basin and the island (Scoglio d'Olivie) was filled in with suitable material, and two sets of railways were constructed of a length of about 700 ft. The foundation of the ways was partly of closely-driven piles and partly of masonry resting on the rock below.

The sheet piling upon the outside of the enclosing walls was cut off, by means of a circular saw specially designed for the purpose, at depths varying from 15 ft. to 30 ft. The exposed ends of the piles remained as footings for the walls, and were covered with quarry rubbish to form a uniform embankment round the walls. After this was done, the interstices in the embankment, and the slight opening formed between the footing piles and the wall, were filled with common sand, such as is used for mortar. This was thrown from a float against the outer face of the walls, and found its way into the crevices between the solid material.

Four plain vertical cylindrical pumps of 32 in. diameter, and 36 in. stroke, with their lower ends 22 ft. 6 in. below the finished wall of the basin, were erected as soon as the pump well was sufficiently advanced in construction to receive them. A pair of tubular boilers, 72 in. in diameter, and 24 ft. long, each provided with a pair of furnaces communicating with a combustion chamber, furnished steam to a horizontal engine. This machinery was used for all the pumping during the construction of the basin, and was left for such occasional pumping and other work as might be required.

The caisson for closing the opening to the basin was built by the Messrs. Rennie, of London, and was found to answer its purpose perfectly. On several occasions the basin, after completion, was pumped quite free of water, and found to be almost perfectly water tight in every part.

By the latest accounts, the basin and railways, as well as the floating dock itself, were rendering good and satisfactory service.

Mr. Hemans, Vice-President, said it appeared to him that the dock-wall was in fact an extended permanent cofferdam of great width filled with concrete, instead of a temporary dam filled with clay. He would ask whether the béton was let down into a dry space within the piles, whether it was dried in the atmosphere before being deposited, or whether it was let down into the water and took its set there? Also, for what reason the walls were made vertical instead of being strengthened by a batter; and further, the time required for the béton to set in the water or out of the water, what was the total cost of the wall, and the manner in which the piles were cut off by the circular saw?

Mr. A. Giles said, that as the dock was only about 300 ft. long, the depth of water about 20 ft., and the rise of tide only from 3 ft. to 5 ft., he thought that to build a solid wall upon a substratum of mud was rather a hazardous way of getting over a difficulty, which would hardly be attempted in England. The ordinary way would be to begin by putting a cofferdam through the mud, to get the mud out, and to build upon the solid bottom. But as the mud was only from 2 ft. to 12 ft. thick, he thought there had been a good deal of unnecessary ingenuity exercised, and it would have been more satisfactory if a temporary cofferdam had been put round what was to have been the basin, and the wall carried up from the solid rock. Under somewhat similar circumstances he had put in a bottom where there was a depth of 30 ft. to 40 ft. of mud to penetrate before the foundation was attained. In doing that he constructed cofferdams in pits of from 6 ft. to 8 ft. square, getting out the mud to the foundation and then throwing in the béton. So long as there was mud under the walls they would be liable to slip and eventually to upset the work. The dock he referred to was 420 ft. long, and the cost did not exceed £63,000. If the outlay for this work for one dock had amounted to £120,000, the cost was heavy.

Mr. Murray said that he thought the béton surrounding wall was not so adequate a means of enclosure as a cofferdam. There could have been no difficulty in obtaining piles of sufficient length and scantling in the locality, inasmuch as they were employed to enclose the béton wall, and if there had been none in obtaining clay he considered it could have been used at a far less cost than the béton. The small thickness of the mud might have been a reason why the cofferdam system was not adopted; but there could have been no difficulty in throwing down clay in the line where the cofferdam was to be formed, and in driving the piles through it, and of obtaining thereby a firm foundation for the piles, even though they struck the rock. He was of opinion that a timber dam filled with clay, and, if none was to be had, even with the mud dredged from the bottom, with probably a little more breadth between the piles than usual, could have been constructed in that locality at far less cost per lineal yard than a béton wall 20 ft. thick. The clay dam, if properly constructed, would have been homogeneous throughout, and no fissures need have occurred, because the bolts might have been fitted with washers hanging loosely in the clay, and they would thus prevent all possibility of leakage.

It might be urged that if the cofferdam had answered the purpose of allowing the water within the enclosure to be pumped out, yet the timber being liable to decay would cause the work in time to become defective, in fact, requiring ultimately a water-tight wall. Now, assuming a cofferdam to have been constructed, it gave the means of permitting débris, or quarry rubbish, to be deposited with a slope on each side of it, which again could have been coated, if necessary, with rubble stones of a larger size to the surface of low water, when either blocks of stone, or artificial blocks of béton, could have been laid upon the deposit and upon the cofferdam carried up to any height and breadth required, thus forming a solid water-tight embankment to the enclosure.

The application of the "spider," for the purpose of driving the sheet piles, was quite new to him. He had often experienced difficulty in driving sheet piles in a considerable depth of water, and had been accustomed to place the main piles 10 or 12 ft. apart, and to connect them with the walings under water by means of divers with helmets or the diving-bell. When these were put on, as well as the upper walings above water, there was no difficulty in driving the sheet piles perfectly tight. But in the plan here adopted the "spider" appeared to him capable of such ready adaptation, that it was scarcely necessary to drive main piles at all, for the sheet piles might be continued one after the other with facility, which was of great importance in driving sheet piles in a considerable depth of water. In cutting off piles with a circular saw under water he had experienced much difficulty by the nipping of the saw; and the detention and trouble arising therefrom had caused him to abandon it. He preferred the common saw with hand labor from the diving-bell, with ropes attached to the heads of the piles to draw them asunder as the cuts were made.

Mr. Bramwell remarked that the question of cost had been put as though the work described were in itself a dock; whereas, if he rightly understood, it was merely the basin to contain the dock, and therefore the amount of money stated did not represent the cost of the dock and basin, but of the latter only. It had been stated that the depth of water upon the stone stringers was 18 ft., and that the basin was 311 ft. long and 211 ft. wide. There were, besides the dock, two short lines of railway in connection with it and the shore, each capable of receiving a ship. Taking the depth of water of 18 ft. above the stone stringers, and allowing for such a floating dock as this 8 ft. depth of bottom, it would leave only about 10 ft. for the draught of the vessel; and if that were so, this would be a very large work for docking small ships. He would be glad to hear what draught of vessel could be docked by these appliances, and whether the £125,000 represented the cost of the basin and railways, or whether it included the dock which was worked within the basin.

Mr. Bazalgette observed that the longer he lived the more impressed he was with the necessity of looking well to the foundations of works of this kind; he would feel disposed to exercise economy upon any portion of the structure rather than on the foundations. He thought that at Pola it would have been easy with a dredger first to have removed the mud upon which the béton had been deposited, and then to have founded it upon the solid rock. In that respect he regarded the work under consideration as an interesting experiment, and he would feel anxious to observe how far this work would, in the course of time, remain in position. He had himself been engaged recently in underpinning and deepening the foundations of two important wharves on the river Thames, which, for want of having been originally carried down to the solid ground, had given way, and the buildings were slipping into the river, after having been built and used 30 or 40 years. He was not able to follow exactly the remarks of Mr. Murray, who seemed to suggest the formation of a clay-dam in addition to the piling round the béton, which would be tantamount to forming an interior cofferdam of clay requiring a solid structure behind it. He did not see that any necessity for such an addition had arisen during the construction of the work. The piles seemed to have been kept in position by being strutted and bolted together and driven through the mud, and the principal merit of this structure seemed to be its cheapness and its simplicity. The béton was apparently allowed partially to set before being thrown into the water, and by that means probably the loss of lime and consequent deterioration of the béton were prevented, which would more or less occur if the béton was deposited, without some counteracting precaution, in an unset state. The plan which he had adopted with advantage was to pass the concrete through shoots so as to prevent the lime being washed out of the mass. Mr. Ridley in his Paper upon the Thames Embankment cofferdam * had given a description of a circular saw for cutting off the pile heads under water, which was supposed to be the first of its kind and had been patented; and, although that was somewhat different in principle to the one used at Pola, it was interesting to know that this advantageous mode of cutting off pile heads at a great depth under water had been employed in other cases and with the same success.

Dr. W. Pole remarked that the plan of dropping concrete into its place through a great depth of water appeared open to objection, as likely to damage the composition of the material and to affect its setting power. Some years ago he had occasion to go with the late Mr. Rendel, Past-President Inst. C. E., to see the harbor works at Marseilles, where concrete was used extensively in building walls under water. The plan there adopted was very ingenious. The concrete, being first properly prepared and mixed, was placed in a box about 3 or 4 ft. square, constructed in two halves, which opened on hinges at the upper part. This box was lowered through the water, and when in its place, by certain catches and chains, worked from the surface, the two halves of the box were separated, and the concrete spread itself quietly on the place it was intended to occupy, after which the empty box was drawn up and refilled. By this means the concrete was deposited

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* *Vide* Minutes of Proceedings Inst. C. E., vol. xxxi., p. 3.

without danger of any of its components being washed away, and it was found to set perfectly in the usual time.

Mr. Harrison, Vice-President, said that if he understood the Author rightly, there was no clay conveniently at hand with which to make cofferdams; therefore, though Mr. Murray had suggested the practicability of constructing cofferdams in deep water, yet to make bricks without straw, as would have been the case here, was quite out of the question. He agreed, on the whole, with previous speakers, that it was most desirable in such situations to build a sea wall on a solid foundation; but he thought the Author had given reasons for adopting the plan that had been followed, which he was not able to controvert without much greater knowledge of all the facts of the case than he possessed. He had seen the same process as that described carried out in a depth of 40 ft. of water at Trieste, where the walls of the harbor were formed of béton within a framing of sheet piling, and in some cases with guide piles only, and planks placed inside, which were afterwards removed. There was not in this country the same material at hand to employ in such works; were it otherwise he was satisfied it would be more extensively used than at present.

Mr. G. B. Rennie said he had visited the works at Pola in 1858 during their progress, and had been conducted over them by Mr. Towle. He understood that this mode of construction was very ancient in the Adriatic, on account of the facility with which the Santorin and other materials employed were obtained; and these considerations in a great degree led to the method that had been adopted in making this dock basin. It had been estimated that the cost of a graving dock, like that at Southampton, of a length of 300 or 400 ft., was about £63,000. Now supposing the basin and railways at Pola to have been constructed at a cost of £120,000 as stated, and assuming that the dock itself cost another £100,000, for that outlay docking accommodation had been provided for five first-class vessels of from 300 ft. to 400 ft. long, and between 3,000 and 4,000 tons weight. That would reduce the cost per vessel to about £40,000 as against £60,000 in the ordinary graving dock. The whole docking arrangements at command, not merely the basin, must be taken into consideration. He had been informed by an Austrian officer that vessels of 2,300 tons, such as the frigate Schwartzenberg, had been actually hauled ashore on several occasions, with great success, from this particular dock. It was evident from what had been done at Pola, that vessels of large size might be taken from the dock to the shore.

Mr. A. Giles remarked that Mr. Rennie's comparison of cost ought to have included the draught of water in the dock. In the Southampton dock there was a depth of 26 ft. of water over the sill at high tide, so that a vessel of that draught could be put upon the blocks. The Pola dock basin represented a depth of only 14 ft., and depth formed a material element in the cost, and ought to be considered in connection with it.

Mr. G. B. Rennie said the Kaiser, a line-of-battle ship weighing over 3,500 tons, had been lifted on this dock, and her load draught-line was 27 ft. The dock was in deep water when it lifted the vessel up, and was then transported into the basin.

Mr. A. Giles said in reply that in that case it ceased to be a dock and became a pontoon, the vessel being floated over a shallow sill; although it might answer all the requirements for docking ships.

Mr. Brunlees mentioned that a few years since, when at Fiume, he noticed some newly-constructed jetties made of concrete; but in that case the concrete was in blocks placed upon a stone bank, built up from 50 ft. to 57 ft. below low-water level to within 20 ft. of the surface. The top of the bank was levelled for a width of 47 ft., the land slope being 1 to 1 and the sea slope 2 or 3 to 1. This bank was formed of stones of all sizes, thrown in from barges and flats, and cost the Austrian Government 2s. per cubic yard; but the cost of the concrete blocks was 14s. 3d. per cubic yard. The concrete was formed from a compost of 6 parts of Santorin cement, 2 parts of slaked lime, and 1 part of sea-sand, which, after being well worked together, was mixed with clean small broken stone in the proportion of 1 to 1. The angles and sides were filled in with pure cement, and the blocks, when finished, were carried about 300 yards.

With regard to the foundations of the walls of the basin at Pola, he observed that if the mud under the wall was very soft, he would have no hesitation in putting the béton upon that mud, because it would sink through it and take its own position on the bottom, and carry the superstructure just as well as if the mud had been removed. If the mud was comparatively hard, then he thought it would have been better to have removed it altogether previous to putting in the blocks.

Mr. J. Grant asked the Author whether be had made a comparative calculation of cost between the plan he had adopted and that of dredging out the foundation, as suggested by Mr. Bazalgette, and putting in the béton or concrete soon after being mixed, or in the form of blocks. Both methods had been adopted in Great Britain and in France. The plan of making the blocks, and of letting them harden for some time before putting them in place, and been extensively adopted. On the other hand, the plan of lowering the concrete through shoots, or by means of boxes or skips made to open, as mentioned by Dr. Pole, had also been followed. Each mode had its advantages. In the case of an embankment wall about to be commenced on the Thames, it had been determined not to remove a certain thickness of sand and fine gravel, which was too deep to be removed within the means at disposal, but on this stratum it had been resolved to form a foundation of two or three courses of concrete blocks, made of ballast and Portland cement in the proportion of 6 to 1. Above these the concrete would be put in after the usual manner as the tides permitted. Timber was a costly material, and he thought that if its cost could have been saved, it would have gone a long way towards making the wall wider at the base and narrower at the top, yet on the whole cheaper. As a general rule, concrete which had to be lowered through water must to a certain extent lose in strength. He had found that if concrete was allowed to commence setting for a certain number of hours after being mixed, and then passed through water, it would not be equal in strength to what it would be if allowed thoroughly to set out of water, or in blocks made and kept for a time above ground. Whatever strength was thus lost in the concrete was an equivalent to an increase of cost.

Mr. A. Giles observed that the Author had asserted that the Austrian Government had abandoned the idea of an excavated dock in consequence of the treacherous nature of the ground, and that the difficulty of constructing a cofferdam and getting the water out to enable them to proceed with the excavation had deterred them from taking that course. But it was stated that four pumps 32 in. in diameter, and with a stroke of 30 in., were sufficient to keep the basin dry with a head of water against it of 20 ft. However, he was of opinion that an efficient cofferdam could have been put up more satisfactorily and at less expense than the system of construction that had been adopted. The basin was 211 ft. wide and 311 ft. long, which gave an extent of wall of 1,046 ft.; now allowing 1,100 ft. for the length of the cofferdam, he thought he could have put it down for £20 per foot. It might have been supposed in the first instance that the cofferdam was not put in because there was no clay readily at hand for the purpose, but it appeared clay was used to some extent, and it might therefore have been found for the cofferdam. If he could have put in a cofferdam for £22,000, he could have built the walls for £20,000 more, or £42,000 for the whole dock; the caisson cost little over £3,000, and these items together amounted to £45,000. There was no mention of cost in the Paper, but that must be taken into account in considering whether a work was well done and worthy of imitation; and it was said that the cost was £125,000. The Author had given 2,200 cubic yards as the quantity of prepared béton, which it was said it took 82 men 18 days to prepare: according to which a man could only prepare 1½ yard of béton per day. That must have been expensive for labor if not for material. If the Author would give the cost of labor, as well as the cost of the work, it would enable an opinion to be formed whether in this country a Balance Dock might be built on a bottom of mud, or whether it would be better to go down to the solid rock.

Mr. Redman said he thought it was unfair to contrast this work with others having a similar duty to perform elsewhere. Graving docks were admirably adapted to the United Kingdom, where there was a large rise and fall of tide; but, in a comparatively tideless sea, they were to a certain extent inapplicable. He considered that the outer basin of this system of dock and slips was laid out for the protection of ships from the sea during the process of docking, under the great changes of weather that occurred in the Adriatic, and possibly also before being transferred to the slipways. In making any comparison of the kind referred to, the cost of the cubical internal capacity of the outer basin should be compared with the cost of a graving dock. This came to considerably over £1 per cubic yard of internal sectional capacity for the Pola dock—a high price. However, this system enabled two or more vessels to be docked *in transitu*, and there were slips or railways in connection with the basin, so that there was available dockage for five vessels; and taking the total cost at £125,000—which were the figures quoted—the cost was only at the rate of £25,000 per vessel.

It had been stated that a large iron-clad vessel had been docked in this basin, in which the available depth of water was from 13 to 15 ft., whereas the vessel referred to drew over 27 ft. of water. This proved that the balance dock could be taken outside the basin, submerged, the vessel put on, and the receptacle pumped out and taken into dock; so that evidently the comparison with ordinary graving docks did not hold.

With regard to the question of forming the foundation of the walls either on the surface of the clay or mud or on the rock, no doubt the walls might have been carried down to the rock by dredging a trench, without—as Mr. Giles proposed—putting in a cofferdam at all, or by caissons or cylinders; but looking at the limited depth of the basin, and the appliances for transferring a vessel to a higher level by means of slipways, such an outlay would undoubtedly have increased the expense of that particular portion of the work, which appeared to be about half the total cost, by about 50 per cent.

Mr. J. M. Heppel said that Mr. Rennie's explanations suggested the inquiry, Where was the necessity of any close basin at all? Because, if the pontoon, or float, or lifting dock, could be submerged, so that it could rise and fall and be floated into the basin, and allowed to settle upon the stringers, and the railway brought to such a level that the ships could be hauled away upon it, then a simple submerged platform at this level without any enclosure would have answered all the purposes required. Mr. Redman suggested that probably it was to protect the vessels from the effect of the waves; but if that were so, there would be no necessity to make the walls so completely water-tight, for if they were intended simply to answer as a breakwater to keep the vessel from being knocked about, a construction not water-tight would have answered the purpose just as well.

Mr. J. Grant asked the Author—

1st. The cost per lineal foot of the basin walls complete, including timber and rubble?

2d. The price per cubic yard of the Santorin béton?

3d. The price per cubic foot of the timber used in the dam?

4th. The general rate of wages paid to the various classes of workmen employed?

Mr. Bramwell remarked that Mr. Redman had spoken of £125,000 as being the total expenditure on the apparatus which would dock the vessels, but he thought that sum did not include the cost of the floating dock, for which probably another £125,000 would have to be added. He would be glad if the Author would state the total cost.

Mr. J. N. Douglass remarked that, in this case, with a depth of water of about 15 ft., and under that a bed of clay varying from 2 ft. to 12 ft., and underlying that rock with a surface dipping from 2 deg. to 10 deg., there were all the elements of unequal settlement and slip, which the Author had ingeniously provided for; the first by the open joint at the end of each section, and the second by the timber key in each of these joints. He thought that by the system adopted there would have been no difficulty in making a continuous béton wall founded upon the rock, and that this could have been done with but little additional cost, and without removing all the mud. One-third might have been dredged down to the rock in sections the whole width of the wall, at equal distances, and those pits when filled with béton would have formed such supports for the wall as to render it perfectly safe from immediate or future settlement. He feared, notwithstanding the open joints had been filled in, that future cracks would occur; and he would ask Mr. Towle whether, in the event of such cracks manifesting themselves again at these weak parts of the wall, he had considered the question of a remedy.

Mr. H. E. Towle, in reply upon the discussion, said that some misapprehension appeared to exist with regard to the functions of this dock. Looking at it as a balanced dock *per se*, if it was used without a basin it would be just as effective, and more so, than the one mentioned by Mr. Giles, built with a cofferdam, which could not be moved; whereas this floating dock could be taken anywhere. As to the dock itself, the floating power of each foot in depth of water was sufficient to lift a weight of 1,000 tons, and a vessel over 5,000 tons had been lifted. It was a question of locality whether an excavated dock or a basin could be built cheaply or not. In this case he had to go many miles for what clay he could get to the limited extent that he was enabled to use it.

It had been asked, Why pump the basin dry? That was for the purpose of getting access to the bottom of the dock in case of repair being required.

The experience obtained had suggested some things which might be advantageously changed or modified if the same result was to be accomplished again under similar circumstances; but the case was an unusual one, and was entirely without precedent, and demanded prompt decision and action.

It was true the Austrian engineers repeatedly came to look at the work, and to see the plans and drawings; but, without exception, till the basin was actually pumped clear of water, they contributed nothing but grave doubts of success, and positive declarations that the basin would be a failure. The basin was not to sink the floating dock in at all, as that operation was performed outside, where the water was about 40 ft. deep; but it was to form a level surface on which to rest the floating dock when a vessel was to be hauled out from, or returned to, the floating structure, or whenever it was desired to inspect or repair the bottom of the dock itself. And, inasmuch as the dock when tested did raise the Austrian ship of the line the Kaiser, which, with its stores, actually weighed 4,223 tons, and at the same time lifted guns and other ballast to make the entire load—ship and all—up to 5,066 tons, he could not assent to the remark, that it was a very large work for docking small ships. Besides, the work would accommodate four more large vessels at the same time upon the railways. In fact, the Pola floating dock would take in and raise a vessel weighing 6,500 tons, and having a draught of 25 to 27 ft.

The problem to be solved was as follows:—A basin had to be constructed measuring somewhat over 200 ft. by 300 ft. on the sides inside. This basin had to be finished with a perfectly level bottom, and capable of sustaining a solid load, uniformly distributed over half of its surface, of several thousand tons. The basin enclosure had to be capable of being pumped dry, both during the period of construction of the bottom and also after the work was finished. The enclosing walls or dam were required to resist a difference of inside and outside water pressure of 20 ft. during the construction of the work, with an outside head of 25 ft. to 40 ft. water; and after it was constructed it had to resist whenever required a maximum difference of pressure, inside and outside, of about 15 ft. of water, the greater head being invariably upon the outside. The site of this basin was in a harbor whose bottom and shores were totally unreliable, and full of irregular cavities and passages of a honeycomb nature. These cavities had, on two different previous attempts to excavate for ordinary stone dock constructions, caused total failures and abandonment of the attempts, with great loss of expended money, which was due to the fact that, at a depth of about 16 ft., the rock bottoms of the excavations were crushed through by the blasting operations, and communications through the cavities directly to the sea resulted. The bottom of the harbor of Pola appeared to be of this unreliable character; but that bottom was covered with a particularly tough material, good for anchorage, from 2 ft. to 12 ft. in thickness. For the first 2 ft. it was soft and incompact; deeper down it became more solid; and where it was 12 ft. deep it was so solid throughout that a steel rod or probe 1½ in. in diameter was with difficulty forced through it by a load of about 500 lbs. weight. A stratum of 4 ft. to 6 ft. of this mud held piles well enough when they were properly connected together above, and less was not safe. This tenacious mud would, exclusive of the upper surface, sustain without yielding, a load of several tons per square foot. It lay all over the site of the basin, in one unbroken tough sheet, covering the rock on which it rested, and covering at the same time all cracks and subterranean and submarine passages and water-ways, which were known to pervade the earth's crust in the vicinity of Pola.

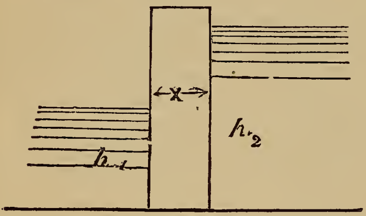
Under these circumstances, and with a site exposed to sudden and violent gales of wind, the question arose, how to build a water-tight basin? Was it safe to remove the water-tight homogeneous and compact natural plaster, or stratum of mud, which in the absence of tidal currents had settled upon the doubtful parts of the bottom? And if so, should it be removed in a trench wider than the base of the wall before forming, and then in some way anchoring the wooden moulds for the béton sections? Or should it be removed within the wall space bounded by the lines of sheet piling after it had been driven in? If removed before the wood-work was put in position, there would have been a depth of 25 ft. to 50 ft. of water, and wooden caissons (sheet piling being out of the question) of at least this height must have been constructed of considerable length, and without internal struts and ties, and at the same time of sufficient strength to be launched from the shore and handled about till adjusted and securely anchored in place. These would have required great accuracy in their construction, that their lower edges might conform to the irregular surface of the rock bottom. Some of them, with the thickness of walls which were adopted, would have been simply huge boxes without top or bottom, and deficient in bracing, and would have had a length of 75 or 80 ft., a height of 40 to 50 ft., and a horizontal thickness of 20 ft., and one such would have taken for its construction about 15,000 cubic ft. of timber, which of the kind available at Pola would have required 225 tons of ballast to sink it.

Again, admitting this system of large portable moulds or caissons to be quite possible of themselves, though a caisson of 25 ft. in depth had been the largest hitherto achieved, he had seen in Pola harbor the frames and caissons of similar moulds of only 12 to 15 ft. in depth wrecked in much less exposed situations, and destroyed in a moderate gale of only a few hours' duration. The enormous cost of this plan would be apparent, without figures in detail, when it was considered that it involved expensive dredging, costly caissons, a greatly increased quantity of béton, to replace the excavated mud, and the difficulties of constructing and maintaining the work intact during its progress. He admitted however without reserve the correctness of the general principle of starting foundation walls from the solid rock, provided it could be carried out practically without counterbalancing attendant evils. Had a trench been excavated for the wall of the basin there would have been risk of uncovering, on either side of the line of the wall, passage-ways through the honeycombed rock, such as caused the failure and abandonment of the works previously attempted for an ordinary excavated dock; and he thought it imprudent to incur this risk when a cheaper and safer method was available for constructing the wall. Mr. Murray seemed to have considered the problem in hand as one more particularly raising the question of the superiority of temporary cofferdams; but the problem was to get a permanent water-tight masonry basin, which could be laid dry at any time under a possible maximum head of about 15 ft. of water.

Béton was the cheapest material as well as the best for the permanent structure; and even if its cost was two or three times greater than that of a clay cofferdam, the latter was not required at all by his method of construction. The object was to build the basin walls as economically as possible with or without cofferdams. To have driven a cofferdam would have been perfectly practicable; but while it was serving its purpose as a dam, the timbers in it could not have been used for the timber-work in the bottom of the basin, as was the case with the sheet piling which was cut off after the walls had hardened. And then, again, the quantity of timber required for a temporary clay cofferdam, and that required for the bottom and other parts added to it, would, to say nothing of the difficulty of getting proper clay, have made an exterior clay cofferdam excessively costly, even with the thinnest possible permanent wall that would have served the purpose. The cofferdam must have been very thick and ponderous if the water was taken out to the bottom rock, which in the northern part was about 50 ft. below the water level outside; he knew of no such dam in such an exposed situation, and it would have been very expensive. The rotative forces on such a dam, the earth being removed from the inside, to be in equilibrium with the mass acted upon by gravity alone, would have required a thickness of between 19 and 20 ft. of wall; and the forces tending to slide the dam horizontally along the rock on which it rested, with a coefficient of friction of 0.25, would require to keep them in equilibrium a thickness of wall of more than 48 ft., and in the deeper water still more. If the inside wall, with such an outside cofferdam, only went down and was made water-tight with the shallow bottom of the basin, then when the exterior dam was removed and the basin pumped dry inside, as it had been repeatedly, the basin itself, if it held together, would have floated.

CALCULATIONS RELATING TO THE STABILITY OF THE BASIN WALLS AT POLA.

Problem 1. Required the thickness of a rectangular wall or dam, 35 feet high, of Santorin béton, to sustain a pressure from sea-water, upon one side having a head of 34 feet, and upon the other side a head of $(34-17\frac{1}{2}) = 16\frac{1}{2}$ feet.



Sea-water weighed 64 lbs. per cubic foot.
Santorin " 120 lbs. "

Let h = height of the wall or dam, and l = length.
h_1 = height of the water outside.
h_2 = height of the water inside,
w = weight of the fluid per cubic foot.
w_1 = weight of the material in the dam per cubic foot.
x = thickness of the dam.

The dimensions are in feet and weights in lbs.

For the (outside) hydrostatic pressure P_1.

The area pressed .... $= h_1\, l$;
Centre of gravity below surface...... $= \frac{1}{2} h_1$;
Density of fluid..................... $= w$;

$$\therefore\ P_1 = \tfrac{1}{2} l h_1^2 w, \quad . \quad . \quad (1.)$$

Centre of pressure on outside, above (a) axis $= \frac{1}{3} h_1$;

$$\text{Statical moment of } P_1 = \tfrac{1}{6}\, l\, h_1^3\, w. \quad (2.)$$

Similarly, for the (inside) hydrostatic pressure P_2.

$$\therefore\ P_2 = \tfrac{1}{2}\, l\, h_2^2\, w; \quad . \quad . \quad (3.)$$

and in reference to axis (a) the

$$\text{Stratical moment of } P_2 = \tfrac{1}{6}\, l\, h_2^3\, w. \quad (4.)$$

Let R = the resultant of the pressures $= P_1 - P_2$; this gave for R

$$P_1 - P_2 = \tfrac{1}{2}\, l\, h_1^2\, w - \tfrac{1}{2}\, l\, h_2^2\, w, \text{ and}$$

$$\therefore\ R = \tfrac{1}{2}\, l\, w\, (h_1^2 - h_2^2). \quad . \quad . \quad (5.)$$

Let z = the distance this resultant acted above the axis of rotation (a), then its statistical moment was

$$R\, z = \tfrac{1}{2}\, l\, w\, z\, (h_2^2). \quad . \quad . \quad (6.)$$

From equations (2) and (4) were obtained the following expressions for the value of this statical moment :

$$R\, z = \tfrac{1}{6}\, l\, h_1^3 w - \tfrac{1}{6}\, l\, h_2^3\, w; \text{ reducing}$$
$$R\, z = \tfrac{1}{6}\, l\, w\, (h_1^3 - h_2^3) \quad . \quad . \quad . \quad (7.)$$

and substituting the value of R in equation (5) and dividing, there was obtained

$$z = \frac{4}{3}\,\frac{(h_1^3 - h_2^3)}{(h_1^2 - h_2^2)} \quad . \quad . \quad (8.)$$

The sum of the statical moments of the water pressures taken with respect to (a) the axis was as above ascertained, (Equation 7),

$$\text{Formula} \qquad R\, z = \tfrac{1}{6}\, l\, w\, (h_1^3 - h_2^3),$$

tending to turn the wall inward. To resist this, there was the weight of the wall or dam itself, and the pressure of the filling of earth upon the inside of the basin, which latter for the present would be neglected.

OF THE RESISTANCE OF THE WALL OR DAM.

The volume of the wall.........vol. $= x\, h\, l$;
The weight of the wall......... $W = x\, h\, l\, w_1$;

Its statical moment about (a) was

$$W \times \tfrac{1}{2} x = \tfrac{1}{2} x^2\, h\, l\, w_1; \quad . \quad . \quad (9.)$$

and for equilibrium

$$\tfrac{1}{2} W\, x = R\, z. \quad . \quad . \quad (10.)$$

Now substituting in (10) the values from equations (7) and (9) and afterwards reducing and solving,

$$\tfrac{1}{2} x^2\, h\, w = \tfrac{1}{6}\, w\, (h_1^3 - h_2^3),$$
$$x^2\, h\, w_1 = \tfrac{1}{3}\, (h_1^3 - h_2^3)\, w,$$

the general formula for thickness was obtained.

$$x = \sqrt{\frac{1}{3}\, w\, \frac{h_1^3 - h_2^3}{h\, w_1}} \qquad (11.)$$

Substituting the numerical values of Problem 1,

$$x = 13\tfrac{3}{10}.$$

Problem 2. To find the thickness (x') a cofferdam must have to stand upon the rock bottom, without either water or earth inside, taking the material at 120 lbs. per cubic foot for the clay dam :

The cofferdam had a height $h = 35+12 = 47$.
The head of water was..... $h_1 = 34+12 = 46$.
$h_2 = 0 \qquad w = 64 \qquad w_1 = 120.$

Substituting in the general formula (11) for thickness,

$$x = \sqrt{\frac{1}{3}\, w\, \frac{h_1^3 - h_2^3}{h\, w_1}} = \sqrt{\frac{1}{3} \times 64\, \frac{46^3}{47 \times 120}}$$
$$x' = 19.1833;$$

therefore for equilibrium against rotation the thickness was nearly 20 feet.

For equilibrium against sliding from the water pressure, which was over 30 tons per lineal foot of the dam, with a coefficient of friction of 0.25, the thickness would have to be more than 48 feet. Of course when the water was deeper, as at the north-west corner of the basin, the thickness in either case must be correspondingly greater.

The plan for removing the mud, instead of building upon it, by dredging to the rock bottom inside the timbers forming the sheet-piling walls, received much attention. No doubt it was the most certain way to found the walls upon a solid bottom, but it presented the disadvantage of greater cost. The wood-work, sheet-piling, etc., would have required bracing and strengthening, and also loading down by ballast, if the interior mud supports to the piles had been removed. The dredging itself in the narrow space of from 15 to 20 ft., encumbered by the upper cross frame-work and bracing and the staging piles, would have been troublesome and expensive. The walls if carried down on an average of 6 or 8 ft. deeper than the water, would have required 20 per cent. more materials in the Santorin béton parts, and their cost would have been increased in this proportion.

It would, he thought, be admitted that so long as mud, or any other material, under a wall could not escape, even if fluid, the wall could not go down by settling vertically. And if such mud in a tight enclosure was so powerfully pressed that its fluid parts disappeared, as the water in a submerged sponge would do in a press acting under water, and left the solid material, which never again would have to sustain as much pressure as it had already received, then such a wall, so far as its mere weight was concerned, had an adequate support. Suppose a great amount of lateral friction were now brought about, by embedding this wall upon either side in such wood and earth work as the Santorin walls at Pola had provided for them, additional vertical as well as lateral support would be given to the wall; in the same way that an ordinary pile got a great share of its sustaining power from side friction. This friction was increased at Pola by the use of fine sand, which was carefully thrown against the outer sides of the walls, and which, by constantly insinuating its particles under the gentle action of the water and of gravity, continued to give increasing stability to the wall.

Reference had been made to jetties in France constructed of béton blocks, but these jetties would allow the water to flow from one side to the other even at a moderate depth. He had made comparative valuations of cost between the method adopted and that including dredging out, and the economy was in favor of the adopted plan.

Respecting the cakes of concrete referred to by Mr. Grant, if he meant small masses of a few cubic metres such as were used at Marseilles, Caen, and some other places, for breakwater works, no estimate was made, for the reason that no plan occurred to him in which such cakes could be of effective service, or at all compete with the large cakes containing 1,500 to over 2,000 cubic metres. That there would have been less material in a wall with a wide base and narrow top was true, but in the present case it was desired to hold the blocks under perfect control during the progress of settling. If the sides of the enclosing wood-work had been such as to allow the inverted wedge form to be given to the cross section of the blocks, any settlement of them would have caused the wall to drop away from the sides, and be free to yield to any forces acting to throw it out of the desired line of the wall, and also impair the foundation. Besides, a width of from 15 to 20 ft. was not too much on the top surface of the walls, and a greater width below would have prevented rather than facilitated the immediate subsidence of the wall to its lowest point, which was promoted by top-loading the walls, and removing the water from one side to a greater extent than would occur again.

The cost of Santorin béton from 1857 to 1860, at Pola, including all materials and labor when deposited in a trench, was about 80 Austrian florins per cubic klafter, or approximately 10 florins per cubic yard. The cost per cubic foot of pine timber in the dam, of 1 ft. by 1 ft., was, at 3 florins 33 kreutzers per lineal klafter, about $\frac{2}{5}$ths of a florin. Round pine piles cost about $\frac{1}{3}$d florin per lineal foot; and very large square oak timber cost 2 florins per cubic foot.

The wages of a mason were ..1½ to 2 florins per day.
" " mortar-maker were.....................1¼ " "
The wages of a laborer were..1 to 1¼ " "
" " carpenter were1½ to 2½ " "
Hire of cart and two horses..5 " "

In May, 1859, a cofferdam was made in the ordinary way at Pola, after the basin had been pumped out, on the other side of the same island, where the greatest depth of water was 15 ft.; but it failed.

Santorin béton had invariably been spoken of as if it were the same as ordinary concrete or béton made with Portland or Roman cement, or of some of the various kinds of hydraulic cement; but this was an erroneous idea. When newly made it was not fit for use until it had been exposed to the open air for a period of from 2 to 6 days, in heaps of about ⅓d of a cubic yard each. This was the size of the batches, compounded of 7 cubic ft. of Santorin earth, and 2 cubic ft. of lime paste, which formed Santorin mortar of remarkable strength, to which was added 7 cubic ft. of broken stone. These together made 9 cubic feet of Santorin béton. When this béton was to be used in water 10 or 15 ft. deep, the heaps were broken with a spade or pick into pieces convenient for shovelling into barrows, coarse and fine together, and simply "dumped" into the moulds in horizontal layers uniformly distributed, which was ascertained by the foreman in charge continually measuring with a rod suitably marked. In depths not exceeding about 20 ft., the cementing materials were not washed away from the fragments of béton and pieces of broken stone, but reached their positions in the wall in proper condition to unite firmly with the rest; but in the case of the deep blocks between 25 and 40 ft. in vertical thickness, he found it advisable to guard against this wasting action of the water during the fall of the béton to the bottom. Baskets, spouts, tubes of canvas, boxes, such as had been used at various works for depositing concrete, which opened in two parts, and cloth bags in which to lower the béton by ropes, and then untie and deposit the contents, were duly considered. But the unusual depth of water and the great quantity of material to be let down—some of the single blocks contained 2,200 cubic yards of béton—and the expedition required to complete one block in a reasonable time induced him to seek a more expeditious way of procedure, and in the end he simply deposited the heaps of 9 cubic feet each in a solid unbroken mass, in the deep water; there the lumps were crushed by iron rammers fastened to the ends of long rods for handles; this expedient overcame all difficulties, and was at the same time the most economical.

The Santorin earth, damp and loose as usually measured from the heap, weighed 50 lbs. per cubic foot. A cubic foot of Santorin earth absorbed 30 lbs. of water, and the simple addition of the water caused the earth to shrink two-thirds its original volume. It was very similar to puzzuolana and was of a volcanic nature; a large percentage was in pieces of about the size of a pea, diminishing down to sand. Mixed with common lime it made a very hard and strong material; and he had seen entire arches made of it, and it was capable of being worked like stone.

THE VALUE OF ARTIFICIAL FUELS AS COMPARED WITH COAL.*

By JOHN WORMALD, C. E.

The question at issue really is, why should artificial fuels be worth considering only during the existence of a coal famine? We are well aware that artificial fuels are in daily use, but I ask to what extent, as compared with the resources we have for producing it. There are thousands of tons annually of really good fuel cast on one side, destroying otherwise profitable land, that, if only dealt with by known processes, would be almost as valuable as the coal itself in its units of work. Rises in the price of coal above the ordinary level are quickly followed by the appearance of this waste in the market, and not till then is it disposed of commercially, after laying for years exposed to the weather during the low or ordinary price of coal; it must be remembered, too, that this residue under consideration, through such exposure, gradually loses in value for heating purposes, and is reduced in bulk through dirt and dust being carried away by wind, partially destroying useful land in the neighborhood, while the slow process of oxidation reduces the percentage of heating power. Thus, if after years of deterioration at the pit's mouth, this stuff is found to be of marketable value, it surely ought not to be allowed to accumulate to the extent it does.

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* The Scientific and Mechanical Society, Manchester.

The question is—that, if for the future immediate advantage is taken of this refuse when brought to the pit's mouth, to what extent will it relieve us? Professor Gardner, at the Polytechnic Institution, London, has been telling us lately that there are about 24,000,000 tons of this smudge or waste brought up to the surface annually, but as he has taken a percentage of a rather high total annual get of coal, viz., 140,000,000 tons — whereas it is, I believe, about 120,000,000 tons—we may safely assume that there is not less than 20,000,000 tons of waste brought up with the present annual production of coal.

There is no reason why at any time this improperly so termed waste should not be made good use of, let the price of coal come down to what it may; and we must hope that the inertia lately given to the fuel question will start enterprise in the right direction as far as this item is concerned. It may be argued that coal dust is used in the manufacture of patent fuels; but whatever is used in quantity there is an undoubted accumulation of this so-called waste, and this waste, if not allowed to deteriorate by long exposure to the atmosphere, may be made as commercially valuable as the selected class of dust.

For domestic purposes I don't think that patent fuels, in the ordinary sense of the term, are well adapted; but if the 20,000,000 tons just referred to was rightly made use of, it would reduce the existing draw upon coal for steam purposes considerably. I have drawn attention specially to this coal residue question to show that it forms considerable bulk when compared with the staple fuel itself, and, as its cost of get or production equals that of the coal, it is of no minor importance that use should be made of it with the best results attainable, especially when we find the demand for fuel in all directions increasing in the ratio that it is doing.

The question now arises: What is the best way of treating this residue or waste? As it really forms the foundation in bulk of patent fuels as a rule up to the present time, it may and will be assumed that there have been various ways of dealing with it so as to make it a fuel of commercial value. Therefore, for the purpose of illustrating superficially what has been done to attain this object, I have referred back to what has been patented directly for this purpose.

We are supposed to find in the patent records all that is of value, and, of course, plenty that is not of value; and I have taken this course of obtaining what little information I can lay before you this evening for the purpose of connecting the fuel history of the past with the present. To more clearly explain the connection, I have considered it worth while to diagram the mixtures in the relative proportions as set forth in the respective specifications, but only in such cases which I have considered interesting for comparison. In following them up we certainly shall find a few extraordinary-looking proportions both in the nature and in the quantities of the several ingredients, but as to the merits of such mixtures or compounds for the purpose required, I will leave the meeting to judge for itself. In searching back through the patent records, the first published specification I can find in connection with fuel is dated April, 1773—exactly one hundred years since. I believe patents for the same subject had been granted long prior to the above date, for I remember some time back noticing in "The Engineer," in one of a series of articles on peat, that a patent was granted to one William Fallowfield, in 1727, "for the use of charred peat in the smelting and manufacture of iron." In the patent of 1773, just referred to, the specification relates chiefly to the purification of coal for smelting purposes, and we may reasonably infer that at this time serious attention began to be paid with respect to fuel, for down to 1792—a period of nineteen years—we find the same John Barber figuring in the patent list, and with the same object.

In the year 1799, which we may call in round numbers nearly three-quarters of a century back, we find the first patent record of a composition or artificial fuel, in which the patentee describes the machinery for separating or screening the coals, taking the small or dust of the same as a base for his fuel, which is to be mixed with any portion or all the ingredients named in the diagrams (1799), in which the various ingredients are simply named, there being no proportion specified. He proceeds to say that they must be mixed together and ground in water in a wooden vessel, after which he moulds the composition into cakes or balls for use. I wish to draw particular attention to this three-quarter of a century old patent, for I think we see there the secret of nearly, if not all, of our patent fuels up to the present day; and it is strange to watch how persistently fresh patents are obtained, almost weekly, for artificial fuels, the component ingredients of which come, in one way or another, within the list before us. The patentee evidently went in for everything and anything that at all stood a chance, and it appears he got exhausted at last when he had to connect "broken glass" with "any other combustible ingredient." In 1800, the year following, we again find a list of ingredients much resembling the former, but it may be noticed that peat is here mentioned, a substance that must have been quite unknown to the former patentee, otherwise he surely would not have omitted such an important ingredient in preference to broken glass. The patentee in this case, too, does not give any definite proportions to his mixture, but specifies that "the proportions of the ingredients vary so as to suit different purposes." The list is given under 1800 to show the resemblance between the two. Twenty-one years later, say fifty years ago, we get a mixture that has, I believe, been used for an artificial or patent fuel to a far greater extent than any other—small coal and tar, in proportion of 3 quarts of the latter to 1 bushel of the former. This is the first patent during the twenty-one years on the immediate subject in question, but I think we may safely assume that during this period artificial fuel must have kept in use more or less, and it seems strange that after such a lapse the patentee of the previous mixture should burst out with such a simple modification of his first specification. Perhaps he had run the full term with the patent of 1800, and no doubt in the meantime he had ample experience from actual practice as to value, both in cost and work, of various mixtures and proportions of the ingredients named in his first specification, and at last comes down to the simple coal and tar mixture made into bricks, and for which he secures a fresh patent. The next mention in connection with combined fuel is in 1824, when we get a mixture of one-third to one-fifth of bituminous coal, and the remainder stone coal, or culm, and I think this was simply mixing the one with the other and using it in the ordinary way. In the year following, 1825, we have gas-tar and clay, with sawdust or tanner's bark, or the refuse of dyers, wood, or any species of wood sufficiently granulated or reduced, or turf, or straw, or bran. The patentee gives a proportion of one fourth gas-tar, one-fourth clay, and two-fourths of any other ingredients, but a proportion that he says burns very bright is one-third tar, one-third clay, and one-third sawdust. The patentee also adds that gas-tar boiled loses much of its smell without materially injuring its quality. He formed his composition into squares or lumps, and exposed them to the weather for a few months.

1826 brings us to a proportion of one-fourth dung, one-fourth sawdust, one-fourth tanner's bark, and one-fourth mud, the above being mixed with sufficient water to bind them well together. Afterwards it is formed into squares, then dried by artificial heat and dipped in hot tar. I really don't think this made a bad fuel, but when we come to such ingredients as tanner's bark, sawdust, and dung, in the large proportions as specified here, we should fail in quantity, whatever kind of a fuel it might make. If we could only introduce a little more of the mud business in our preparation of artificial fuels I'm sure it would be hailed with delight, especially by our corporations.

We now pass over a period of seven years, during which time artificial fuel productions—as far as patents go—lie dormant, but in 1833 we have a specification claiming a mixture of sea coal with brick earth, blue clay, river sand, or deposits of running or stagnant waters. The proportion of coal to be equal to that of either of the other materials, and to be mixed like mortar with tar and made into cakes or balls. The ingredients here contained may be taken from the 1799 list, substituting the river sand for broken glass.

Three years later, or in 1836, we get an extraordinary combination of ingredients, and, from the finite proportions of certain of them, I should imagine that the specification is the result of a long and tedious series of laboratory experiments and tests. The patentee begins with peat, of which he takes one ton in its raw or charred state, and to this he adds 30 lbs. of crude nitre, 14 lbs. of alum (for preventing smoke), 14 lbs. of linseed, 14 lbs. of resin, asphalt, or naphtha, 150 lbs. of coke, 168 lbs. of green vegetable matter and 156 lbs. of animal excrements or other animal matter. For use the mixture is formed into bricks. I cannot say how the peat was dealt with so as to amalgamate properly with these particular substances, but there must have been some means of masticating or triturating it, otherwise perfect mixing would be impossible, as also the formation into bricks.

A year later—1837— we reach the first mention of treating peat alone, as far as concerns operations for the purpose of converting peat, moss, turf, or bog into fuel. It is first cut up or triturated, and then compressed and dried by artificial or other means; hydraulic presses, levers, and screws are mentioned amongst the appliances for compressing.

In the same year we get a well-known name in connection with fuel. C. Wye Williams mixes peat, after mastication, with sand finely powdered, limestone powdered or ground, coal slack, or quick or hot lime. I should in this case expect that the expense of first preparing the peat for mixture, and added to that the cost of grinding or powdering the limestone or sand, would not tell favorably as regards a marketable price in comparison with coal, especially of late years.

About this time the artificial fuel question seems to have received a considerable amount of attention, and in 1838 I find five patents secured for the same. The first of that year illustrates how we still keep to the old ingredients, with perhaps a slight variation in proportions. The patentee in one case adds to one ton of small coal 30 lbs. of tar, 180 lbs. of dry mud, clay, or marl, then mixes with 50 gallons of water, and adds 30 lbs. of lime or chalk. Again, to 10 cwt. of coal dust he adds 5 cwt. of peat, 5 cwt. of sawdust, 200 lbs. of clay or mud, 30 lbs. of lime, and 30 lbs. of tar, the whole being mixed in water and then formed into bricks. Another of the mixtures of the same year is: 7 parts of fullers' earth or strong blue clay, 2 parts of tar, 8 parts of small coal, and 3 parts of mud, the mixture being then formed into bricks for use. I certainly should think this a doubtful fuel, considering there is 50 per cent. of clay and mud to 50 per cent. of small coal with tar in it. Again, in the same year we get 10 per cent. of tar, 18½ per cent. of cinders, peat, or sawdust, 18½ per cent. of clay, sand, or chalk, 50 per cent. of small coal, and 2½ per cent. of acids for another combination. We also in this year again find C. Wye Williams patenting a means of preparing peat, moss, or bog, by pressing it or mixing with it bituminous matter, and we may close the year 1838 with a mixture consisting of 13 cwt. of coke, 4 cwt. of clay or mud, and 1 cwt. of liquid pitch.

In 1839, there is again repeated the "obtaining a fuel by mixing tar or bituminous coal with inferior coal dust;" this is followed up in the same year by Lord Willoughby d'Eresby, patenting the compression of peat in the raw state, and without cutting it up.

In 1840 we find a specification of a mixture to be employed for buildings, mouldings, castings, statuary, imitation of soft or hard rocks, etc., and also to be used as a fuel. Whether any buildings were ever constructed of this fuel or not I am not in a position to say, but I should imagine that the insurance companies would fight shy of them. While upon the subject, I may as well mention as a proof that even now there are people who, with the patentee of thirty years past, believe that for some reason or other it is advisable to construct our dwellings of fuel, for in a specification relating to building materials, dated as recent as last September, I find the following as an abstract: "The said invention relates to a novel treatment of bricks, unburnt clay, soft stone, chalk, plaster of Paris, and other like porous materials, whereby a new material is obtained, which possesses many advantages for building and other purposes. To accomplish this object the inventor takes common bricks, blocks of sandstone, or the other material to be used, and saturates the same with boiled coal tar, melted pitch, or other similar substance."

In the same year, 1840, we find 400 lbs. of tar and 105 lbs. of clay to one ton of small coal, made into bricks, followed up, four months later, by 20 lbs. weight of pitch to 1 cwt. of coal dust, moulded into bricks.

The year 1841 gives us three patents connected with artificial fuels, none of them varying from previous mixtures, with the exception that one of them contains ground slate.

In 1842 we find five specifications, the only one worth mentioning, specifying chalk lime, soft stone, bricks, all broken into small pieces and saturated with tar, and then used in the same manner as we use ordinary coal.

In 1843 we again get five patents relating to artificial fuels, one specifying certain proportions of pitch, coal, and coke ground together, and for every ton so ground is added 6 lbs. powdered resin, and 3 gallons of boiled linseed oil; another gives 10 per cent. of pitch or coal tar to 90 per cent. of small coal, and to prevent smoke, there is added 2 to 5 per cent. of common salt dry, or alum dissolved.

In 1844 there are three patents connected with the subject, one of them being "for machinery for getting the moisture out of peat." At this time there seems to have been a fresh impulse given to the fuel question, very probably in the anticipation of locomotive requirements, for in the year 1845 there are seven applications named in artificial fuels, chiefly of the ordinary character, with the exception of one. The specification gives as this mixture: Gutta-percha 3½ parts, coal dust 4 parts, sawdust 2 parts, and coal tar ½ part. Whatever may have been the patentee's idea of the cost of such a fuel at the time, it is pretty conclusive what our own opinion would be now, when we look at the proportion to the whole of such an extraordinary ingredient as gutta-percha and its value. In the same year we find the usual mixture of coal dust with tar, and sometimes added a small portion of chloride of lime, or chloride of soda, or chloride of potash, to take away smell during combustion. We have at the same time "cementing coal dust with Ransome's silicious paste;" perhaps the latter might be used as suggested before, namely, for building materials.

In 1846, although we get six methods of treating fuel, they are of a very ordinary character and the only change is one mentioning the saturation of peat with tar, oil, etc.

In the year following there is a complete dearth as far as fuel patents are concerned, for there is not one registered for that year; but in 1848 we again get a start with four; but I find that there is still but very little deviation from former mixtures.

For the three years including 1849-50-51, I find nineteen patents recorded in connection with the artificial fuel question, but as a rule, many of them are merely repetitions of what has been enumerated before. One names nothing but tan and resin, which I should imagine might make a very good fire-lighter, although it is not included in that category. The only other worth referring to within the time I have just named is a peculiar treatment of peat, patented in 1850. The following is an abstract of the specification:—"Without previously drying the peat we treat it with waste by a mill in a way similar to that in which chalk is treated in the manufacture of whiting. The resulting liquor is made to pass through a strainer of wire work fine enough to prevent the passage of the large fibres into the tanks or backs cut in the earth, or built upon the surface of the ground if necessary, where it is left to deposit the finer parts of the peat. When this is effected the supernatant liquor is run off from the deposit, and the magma taken out from the tanks or backs and dried either by the air or sun, or on arches of bricks or other absorbent material heated by flues underneath."

In 1852, out of seven specifications relating to artificial fuels, I find one for dissolving peat in a chemical bath and then letting it dry; and another specifying one-twelfth of caustic lime, and one-twelfth of peat charcoal added to ten-twelfths of cut peat, mixed into a cement and moulded.

For the year 1853 I have selected two, out of a total of nine applications during that year. The first I give on the ground of its peculiarity, being composed of one-third of sea mud to two-thirds of sea-weed, and to 2,000 lbs. of this mixture is added 4 lbs. of nitrate of lead. Whether such ingredients would or would not make a decent fuel I am unable to say. The second specification for the same year shows how the same ingredients, that are now old to us, are still being used and in what proportions; but the patentee in this latter case goes in for moulding his mixture in various forms, and altogether departs from the usual antiquated brick form. During the same year we meet again with the small coal and tar business in the brick form, and in the specification I find a description of drying peat by heated revolving cylinders; while yet in another we have the treating of peat chemically while in the pugmill.

Out of a number of eight patents in 1854 for fuel there is not one of interest apart from what has already been shown, with the exception of one I may mention that is solely for the form or shape of any mixed or artificial fuel, the configuration being various, and having holes or passages through them for the purpose of better combustion.

In 1855 we number six patents.

A mixture for 1856 well shows the extremes that are adopted by different patentees in proportioning the ingredients: take here the enormus bulk of clay, 83 parts to coal 15 parts—to me rather an extraordinary proportion; if it was not we should I think have heard more of it than what I am telling you now. There are nine patents for this year, but the one referred to is the only one worth notice, and that on account of its peculiarity.

During the year 1857 there is not anything worth mentioning, and in 1858 we get rye-flour as an ingredient. We again have ground peat mixed with tar.

In the year 1860 the number of patents fell to four, and the only one I shall notice gives equal portions of human or animal excrement, sawdust or chips, and small coal, and to this mixture add one-sixth part clay.

The most novel from the 1861 patents, of which there are five, relates to making boxes of wood about the size of a brick, then filling them with coal dust, and afterwards closing them up; in fact, it is enclosing a brick of coal in a wooden case, and then using it for fuel—a rather expensive method I should think of using timber as an ingredient.

In 1862 there are four patents for artificial fuel, but not anything of unusual interest.

The year following we again hear of seaweed treatment for fuel purposes. In one specification I find lime saturated with tar, which, after being used as a fuel, will, when ground, make a good cement, certainly a profitable way of dealing with the residue, especially if there is any real good in the fuel portion of the method. These two, out of five patents for 1863, are the only ones worth attention, with the exception that the last named process was duplicated by a subsequent patent a few months afterwards.

In 1864 we reach up to nine patents in connection with the subject, and one is peculiar in its ingredients. The patentee seems rather doubtful as to the proper relative proportions, for he names peroxide of manganese, 1 lb. to 10 lbs.; sulphate of lime, 5 to 50 per cent.; coal or coke, 100 lbs.; rosin and asphalt, 2 per cent.; oils, 7 to 12 per cent.; rosin or pitch, 12 to 20 per cent. In the remaining patents we have 90 parts of coal to 10 parts of cow dung twice over; we get also equal portions of peat and charcoal pressed together. The only other worth mentioning specifies cutting peat into blocks, putting them into an air-tight receiver, exhausting the air and moisture, and then admitting petroleum or any like substance.

I have placed one of the three 1865 patents among those worth notice as a novel composition; we have been in want of one lately, and I think this supplies the gap. We get 20 lbs. of meal to 3½ lbs. of pitch or tar, and 2½ lbs. of alum. It might make a very good fuel, but I am in doubt as to both supply and cost of the chief ingredients. One of the remaining patents treats only of the configuration of any fuel.

In the next year the number of patents doubles, but there are not any of interest with the exception of one I may mention, which gives to 1 ton of coal, 2 cwt. of sawdust, 40 gallons of tar, and 2½ cwt. of salt.

The year 1867 reaches ten patents on the subject, and all of them of what I may term the ordinary type. One is simply the coal and tar brick with holes pierced through as in 1864; another combines resin, glue, and salt with coal dust at a proportion of 50 lbs. of the mixture to the ton of coal.

In 1868 we again get ten patents on the same question, and I have selected two for the purpose of noticing the difference between the simple and the compound. In the first case we have 8 per cent. of coal tar to one ton of coal moulded into bricks. I suppose it is due to the simplicity of the idea of glueing small coal together with tar that we find it so often mentioned, but I wonder if the patentees could be aware of the age of the mixture at the time of securing their patents, when no doubt it was as common an article in fuel commerce as it ever has been. The second case gives very careful proportions of delicate ingredients, for, it is stated, to 17½ cwt. of coal dust and 2½ cwt. of clay, must be added 5 lbs. of rice, 5 lbs. of Indian meal, 5 lbs. of resin, and 20 lbs. of asphalt. I believe the smaller portions are admitted to gain the object of combustion with less smoke than ordinary fuel. In the same year we have two patents with the same ingredients and proportions as nearly corresponding as possible, viz., to 1 ton of duff add 2 cwt. of pitch and 2 cwt. of salt, and in the same year we again find turf saturated with oils or other like substances.

During 1869 out of six patents I may mention two of precisely the same treatment, viz., about 8 per cent. of rosin to coal, and another where carbolic acid is introduced in the proportion of 5 gallons to 1 ton of coal, together with 56 lbs. of pitch and 8 lbs. of salt.

In 1870 seven patents are recorded; as the date is nearing the present, I have taken three for the sake of comparison with former years. In the first we get the 10 per cent. of pitch, to 90 per cent. of coal and some sea weed, the proportion of which is not stated. The second is a compound of silicate of soda, salt, lime, and sulphuric acid, to which mixture 15 per cent. of coal is added. The third patent is certainly not novel, but suffices to trace the likness as we go on. We also hear in that year, of human excrement mixed with charcoal, of chalk with charcoal and pitch, and another arrangement of taking small coal and grinding it to a powder, and then mixing it with pitch or tar. We must bear in mind this is the year 1870; what the patentee's idea could have been respecting the cost of a fuel that required coal to be ground to powder, at a time when coal itself was at its lowest, seems strange; but even at the panic prices such a fuel could not, I think, have competed with coal; moreover, I cannot understand why the coal dust should be ground at all, let alone "to a powder."

We lower to five patents in the following year (1871), but I take two illustrations to show, in the one case the costly production, and in the other our old friend up again associated with a little food. As regards the first, to take 25 per cent. of creosote oil to 68 per cent. of coke, and add 5 per cent. of bituminous coal, and 2 per cent. of lime, cannot pay commercially, or compete with ordinary fuel. In the second we get our usual 1 ton of coal, to which is added 100 lbs. of pitch and 10 lbs. of farina, an ingredient we have met with before under another designation. I may remark before closing up this year of 1871, that we have mentioned in a specification a mixture of blood and lime with small coal.

For last year, 1872, I find nine patents recorded, and again of the stereotyped combinations. One patent 12 months ago is nearly similar to the patent of 1821. From this we may judge what progress has been made in the last 52 years, as regards artificial fuels of this particular class, and remember, of a class that has been found the most economical in production; possibly, too, the most efficient for the purpose for which it is required. It is needless to give farther trouble with abstracts of specifications; sufficient, I think, has been shown to illustrate a doubtful progress in the artificial fuel questions, and although we have had, subsequent to the last patent, and continue to have, applications for patents for artificial fuels, especially of late, there is not any thing new in them. Really some of the latest specifications read almost as copies of I may say, dozens that have appeared before.

In taking a retrospect of the various means of compounding an artificial fuel, the question arises, what material have we in quantity that is available for heat-producing purposes to anything like the extent required for relieving the draw upon the coal itself. I think we may assume that the coal residue is disposed of, or will be in the future, in a satisfactory manner, without those mixtures that appear on the diagrams more like "household receipts" than an article of consumption demanded in millions of tons annually. We have had in consideration sawdust, tanner's bark, asphalt, resin, and almost everything that will burn at all; but whatever use the whole or any part of these constituents, by addition, may serve towards making a good heat-producing fuel, it will be admitted that, for general purposes, even taking domestic consumption alone, the quantity collectively at command is anything but equal to the demand; and taking it for granted that certain admixtures will, laboratorily, give certain results in percentage of heat or work, it must be remembered that the requirement is a very great and a national one, and consequently any substitute for coal that may be introduced must be simple and not compound.

Combinations must naturally be expensive, if only from a mechanical point of view, whatever may be the value of the ingredients, even supposing we had quality; but while there is a query respecting quantity, coupled with the cost of quality, I think we can only arrive at the one conclusion, viz., take the most quantitative substitute, and at the same time the most simple, and see of what value it is, and how it can be dealt with to perfect it sufficiently to form a relief to coal.

The next, as compared with coal in quantity (putting quality on one side at present), is "Peat," the half-brother to coal. For the sake of comparison, I will take the relative areas of coal and peat as generally estimated for Great Britain, viz., coal about 7,750,000 acres, and peat about 6,000,000 acres, and taking peat as averaging double the thickness of coal over the estimated area, we get 12,000,000 acres of peat as compared with 7,750,000 acres of coal of the same thickness as peat; this is in bulk. Again, take peat in its condensed form as equalling one fifth of its average original bulk, we then get 2,500,000 acres of peat equal in density to coal, or say, one-third. It must be borne in mind, however, that coal has been worked to an extent quite different to peat, consequently we may infer that the present actual relative proportions between the two must be much more in favor of peat than these figures represent.

In passing, it will be as well to notice here why the question of manufacturing peat into a marketable fuel is of, I consider, great importance in more respects than one. In the first place it has the unequivocal advantage of being procurable upon the surface of the ground; and whatever may have been the difficulties heretofore, or even at present, as regards drainage, cutting, and general treatment of peat, it must be admitted that this one desideratum is strongly to be encouraged. Morally speaking, it is advisable to dwindle down as much as possible the extent of the almost inhuman labor below the surface compulsory for the production of coal—and labor that very few of those uninitiated could by any stretch of imagination anticipate, even excluding the risks that are in constant attendance upon such labor—and also take into consideration the ultimate result of the process upon the human intellect, as exemplified only too visibly of late, a result which gave rise at the moment to the controversy of how to economize an article of consumption that necessitated such uncivilized labor for its production. Of course, we know that the whole of this undesirable labor cannot be dispensed with at once, but we must confess that it is desirable to aim at such a purpose, and, by the utilization of peat and the introduction of coal-cutting machines below, we may soon anticipate a reduction in the extent of underground work.

Respecting the calorific power of peat, as compared with coal, I think we may safely assume that it reaches, in efficiently worked and well dried peat, an average of 75 per cent.; naturally the percentage varies considerably with different qualities of peat, some results being much higher and others much lower, but I think the above to be a fair average.

We next come to the question, "Why has peat been so little known generally as a valuable fuel, although staring us in the face by thousands upon thousands of acres in various parts of the country?" The answer is, that peat in its natural or raw state contains, according to the depth from surface and nature of deposit, a very great percentage of water, and it has been the disposing of this water that has proved the real difficulty in the way of producing peat as a fuel to at all compete with coal.

In referring back to the year 1800 we find peat mentioned in the list, but it is only stated as one of the ingredients of the mixture, and it does not specify how it is proposed to treat it so as to make it available for mixing; but in 1837 we have mention of "Operations for the purpose of converting peat moss and peat turf or bog into fuel." It is stated to be first cut up and then compressed and dried by artificial or other heats; and there are several methods named respecting the compression, such as hydraulic presses, levers, and screws.

We all know that for many years past machinery has been in operation for converting peat into a commercial or marketable fuel, and there are hundreds of tons of it being used; but still the question is, why only in hundreds of tons, when it ought to be, I may say, hundreds of thousands of tons? The answer is, as I said before, that the expenses incurred in trying to get rid of the water to an extent that will bring the specific gravity of the peat to something approaching that of coal, are so great, that it has been impossible to place it before the public in competition with coal in a commercial point of view, at the low prices coal has been standing at for years, until lately; and it is only in such cases as the late crisis that latent energy is wakened up for the purpose of seeing what can be done. I maintain that, let the price of coal come down to its own standard, or even lower, we must not lose the patent fuel question out of sight now that necessity has compelled us to grapple with it. We know how easily circumstances are allowed to fall into their normal state after an excitement is over; but this is a question of national importance, and now that it is proved that peat can be treated in a manner that will almost bring it down weight for weight in equal bulk with coal, and that it can be brought into the market at a much less cost than coal at its cheapest, I trust that we shall soon have it as common an "household word" as coal, especially for domestic use. At the Dartmoor prison peat has for a long time performed every function required of coal; it warms the whole place and is also converted into gas for their own consumption, and all this is done with peat in a much more imperfect state than it can now be produced.

It may perhaps be interesting here to glance at the methods employed in treating peat, and the results obtained. I will again revert to its remarkable power of retaining water; when simply dried in the air, without any preparation, it will only part with about 70 per cent. of its moisture, no matter how long the exposure. If moderately cut up, or macerated, and then pressed and air-dried, it will still keep back about 20 per cent., and it must be borne in mind that the more the moisture retained, the less the calorific power of the peat; consequently, the drier the peat can be produced the greater the heating power. The great desideratum, therefore, is to get rid of the whole of the moisture, and if not all, as much of it as we possibly can. Artificial means of drying after compression have often been tried, but, even supposing that such a process resulted in a production as perfect as could be wished, the very fact of having to consume fuel to obtain the result, upsets all economical views of the case and thereby makes it too expensive for competition with coal.

To get peat to be universally adopted it is imperative that in the first place it must be freed from the whole of the moisture, or next door to it, for in a perfect condensed state it will give its greatest value in units of heat and take up the least stowage, which is very often a consideration; in the second place, it must be produced at a much less cost than ever coal can come to, otherwise it will never be of commercial value.

To gain these points there is only one way of getting at it, viz., thorough mastication or trituration of the raw material. I emphasize the word "thorough" for the reason that if the fibrous rooty portions of the peat are not cut up minutely, so as to release the water and air previously held fast by capillary attraction, you will never get rid of the moisture. Then after thorough mastication, simple exposure to the atmosphere for drying, and not artificial means. From the controversy on this question some time ago, it appears that this approach to perfection, if we may so call it, has only lately been accomplished by Clayton's machinery, which in my own judgment seems in design to be undoubtedly the best yet adapted for the special purpose, and certainly from the results obtained I think we may now hope speedily to see the thousands of acres of bog, now so much waste land, being made use of to an universal benefit.

The machinery in question accomplishes what has long been aimed at, not only in the mechanical treatment of the material, but I believe in cost of production as well; but as it is not the purport of this paper to subscribe or advocate any particular machinery or process for manufacturing either peat or other fuel, sufficient will have been said on that point.

The real object of this paper has been to glance rapidly through the past history of artificial fuels for the purpose of comparing with the present enthusiastic attempts that are being weekly brought to public notice through the patent lists as new, and to note what advance has been made; but if you take the trouble to peruse some of the latest, and very latest, specifications—and some of them are not very long—and then turn to the diagram list of 1799, you will find the same ingredients anticipated, although proportions may vary, which has been the case, more or less, ever since that date. I think, therefore, you will agree with me that as far as compound artificial fuels are concerned there has been no real advance, for to compare at all with coal it must be simple and in quantity.

The only advance of real good, seems to be the stride lately made in the manufacture of peat; and if the quality and marketable price only turns out what is promised, and I do not see any reason to doubt the good faith of it, I think we may congratulate ourselves and the community at large in having the question at last solved, of being able to procure a fuel in quantity and of a quality combining cleanliness in its purchasable form, together with a bright fire, less smoke, and still less residue during combustion.

In conclusion I will reiterate the hope that the time is not far distant when we shall see vast tracts of what is at present so much waste and useless country swarming with industry on the surface, which both physically and morally will be something towards alleviating the wretched labor at present required below the surface.

NOTES ON COPPER.*

From "The Mining Journal."

A mixture of metallic copper and sulphur, even at ordinary temperatures, will gradually combine, but far more rapidly on being heated, and will form sulphide of copper, or, as chemists term it, bi-sulphide of copper, in which for every 64 parts by weight of copper there are 16 by weight of sulphur.

If we take metallic copper, melt it, and keep it exposed to the air, oxide of copper is formed; but what is remarkable, the oxide of copper has the property of dissolving in the melted metal, and thereby changing its working qualities in a most remarkable degree. You cannot then hammer it either hot or cold; it breaks under the hammer, and the broken pieces show a color and character different from that of an ordinary ingot of copper. It has a red color, but verging towards purple, and there are none of those bright shining metallic grains which you see in a good piece of copper. There has been some difference of opinion as to the quantity of red oxide melted copper is capable of dissolving. From experiments made here some years ago, we found that in some cases the proportion might be 10 per cent of the oxide, and in some cases even more. When such copper is melted and ladled into an ordinary ingot mould, on cooling it will be found to have set with more or less of a furrow running down the middle of the ingot from end to end. The copper in this state is called in smelting works "dry copper;" it is quite unworkable. If now we have a quantity (say 8 tons) of the melted metal in a large furnace, if we cover the surface with small coal or charcoal, and leave it for some time, that will remove the oxide of copper, taking away the oxygen—that is, the oxide of copper will be reduced by the charcoal. To hasten the process it will be necessary to stir up the mass so as to bring more of the mass of metal into contact with the charcoal. The simple expedient for effecting this in copper works (refining works), is to take a long pole, about 15 ft. long, of green wood and plunge it into the midst of the mass of molten metal, and keep it there. The wood is rapidly charred; there is a great quantity of vapor evolved, and therefore, great ebullition or boiling takes place in the mass, and thus the copper is brought rapidly in contact with the overlying charcoal and the reduction of the oxide promoted. This operation is termed "poling." After the coal or charcoal has remained for a certain time, we will take out bits of metal to see what change has been effected, and test them by breaking them; and such a trial is made every time a mass of copper is refined. It is not required to take the red oxide wholly out; we shall find by means of the trial pieces, taken out time after time, that the metal becomes more and more tough, more hammerable, and at last, the refiner says, the copper has got its highest degree of toughness (he knows exactly from experience when this point is reached); at that moment the operation of "poling" is stopped, the pole is removed, and the copper is ladled out into ingot moulds. In this state it is said to be at "tough pitch," and it is moulded into more or less square cakes, and called "tough cape copper," suitable for the coppersmith; it can be hammered out and rolled perfectly. In the ingots formed by this copper we shall no longer find the furrow down the centre; it has set with a smooth face, and only a few cross wrinkles. If you try to break this copper with a hammer, you will not succeed, whereas a smart blow would readily break the "dry" copper. When the former is broken, on examining the surface of fracture, we shall see that the color is a characteristic fine salmon red; it will have broken with an even surface (in the former case with a rough surface), and we shall perceive in the centre what appear like small shining grains, but which really are small cavities broken across. It is usual to add to the metal before ladling into the moulds a certain quantity of lead—say, 14 lbs. to 8 tons of copper, though in some cases, when much foreign matter is present, as much as 80 lbs. are added; the lead making the copper set with better face, and more soundly.

Suppose, in the next place, we have kept the charcoal or coal too long on the molten copper, another kind of change will take place. When poured into an ingot mould we shall find it set with a ridge down the centre from end to end; it will again have

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* From a lecture at The Royal School of Mines, by Dr. Percy.

become brittle and unworkable, and no longer hammerable. The color will have changed to a fine orange tint, and we shall observe tube-like cavities in the metal, as though some gas had escaped in the act of becoming solid; it will appear coarsely fibrous; the metal is said to be "over poled." There is considerable dispute as to the cause of this change. We made many experiments here some years ago on the subject. You must remember I am speaking to you of commercial copper, which is not perfectly pure; few men in the world have seen pure metals. In this operation of "poling" we must only proceed to a certain extent with regard to taking out the oxide of copper; if we destroy the whole of it, or reduce it to too low a percentage, we get "over-poled" copper. "Tough pitch" copper has 3 or 4 per cent. of red oxide in it, and it seems to be this red oxide which gives to the metal its workability or malleability. It has been said that "over-poled" copper contains a larger percentage of oxide than we found, but I believe our results were correct as far as they went. I have dwelt upon commercial copper. If we take chemically pure copper, and expose it to charcoal at high temperatures, we cannot "over-pole" it. Commercial copper contains certain foreign ingredients; the conclusion is that when these are present, to neutralize their effect upon the copper we must have a certain proportion of red oxide of copper in the mass.

In the year 1848 I had the honor of giving a lecture on the subject of copper smelting before the British Association at Swansea. I thought that I would prepare sundry specimens of copper, showing what would vitiate it. I got some "best selected" from the market, and melted it, and then I thought I would have some rolled, and so took it to a friend of mine at Birmingham for that purpose. To my astonishment, this quantity of metal, after being melted, would not roll at all, but cracked in all directions. I found that the addition of a certain quantity of various foreign ingredients, and notably a small quantity of phosphorus dropped into it, produced a perfectly workable metal. A small quantity of arsenic did very well, but I do not think anything gave a sounder ingot than a small piece of phosphorus. If we take pure copper, and melt it under certain conditions—*e. g.*, under a layer of charcoal—then we get a sound ingot, which will work admirably; or, still better, if we take this pure copper and cast it in an atmosphere of coal gas, which we can do by having a hole in each end of the cover of the ingot mould, letting the gas stream in at one end, and burn as it issues at the other, and then pouring the molten copper down in the middle of the flame, in this way we can get a magnificent ingot, or even by melting it under charcoal, and pouring it into a mould, taking care to let the molten metal come in contact with as little air as possible.

Perhaps it will have occurred to some of you that if the carbon or the charcoal united with the copper, as we know it does with iron, it might produce the effects of "over-poled" copper. I made some experiments at one time on this subject; I took some finely divided copper, and mixed it with a large quantity of charcoal, so large a quantity of charcoal in fact, that when I afterwards subjected the mixture to a temperature above the melting point of copper for a long time, the globules of melted metal could not fall down and form a layer at the bottom of the vessel, but would remain surrounded by carbon. If copper would combine with carbon, surely this is a condition in which the combination would take place. The pot was taken out of the fire, and allowed to cool, and then cast into an ingot; the ingot was most diligently searched for carbon, but not a particle could be discovered, so that we are warranted in believing that copper does not form a compound with carbon, and we cannot ascribe "over-poling" to the presence of that body in the metal.

An amount of phosphorus in copper equal to $\frac{1}{2}$ per cent. makes the metal wholly unworkable while hot; it becomes brittle or "red short," but it can be rolled when cold. The copper, by the addition of this small percentage of phosphorus, is greatly increased in strength. After I mentioned the fact many experiments were made at Woolwich on this phosphorized copper, in hope of adapting it to guns, but it was not successful. By increasing still more the proportion of phosphorus to about 1 per cent., they nearly double the tensile strength of the metal. If you take some of this copper from the market, melt it, and pour it into a closed ingot mould, on cooling it will shrink or contract; but the ordinary copper, instead of shrinking, expands or rises up. Here is a bell, cast of a specimen of copper to the amount of 11 per cent.; it is a very hard metal, nearly white, but tarnishes rapidly in air; this bell gives a good clear sound, but not equal to that of the regular bell metal, which is an alloy of copper, with about 24 per cent. of tin. When I showed the specimens of phosphorized copper to Mr. James (now Sir H. James), then chief engineer at Portsmouth Dockyard, he asked me to let him try the effects of sea water on them, and he found that of all the specimens, that containing the most phosphorus was least acted on. Thereupon he made an application to the Lords of the Admiralty for experiments to be tried on a larger scale, which was granted, and I procured further specimens for him. In the course of the preparation they came to me, and said they could not roll the copper when hot, but at ordinary temperatures it rolled perfectly. Two buoys were covered, one with phosphorized and one with ordinary copper, and although, through some mistake, they were painted, still it was found that the former was not acted on by the sea water so readily as the other. Here are specimens of phosphorized metals from the International Exhibition of last year, said to be of gun metal, with a certain proportion of phosphorus, said to have greater hardness and greater strength than bronze, and can be used for cutting instruments, for pistols, etc., and are especially adapted for use in gunpowder works. Mr. Abel found that to get perfectly sound castings of phosphorized copper it was necessary to use a metal mould; sand would not do.

The presence of impurities in copper interferes with its power for conducting electricity; the conducting power of pure copper being 93, an addition of a small quantity of phosphorus brings it down to 7 or 10. A small quantity of arsenic dropped into melted copper has the same effect on the workability of the metal as phosphorus; every specimen of copper occurring in commerce contains traces of arsenic, and sometimes more than traces; in some specimens of Spanish copper as much as 2 per cent. Silica or sand is a compound of an element like a metal called silicon and oxygen; this silica has the property of combining with iron, and giving certain qualities to it; it is an almost invariable constituent in pig iron. If you take common sand, and mix it with finely powdered metallic copper and charcoal, expose it to a high temperature so as to melt the copper, and the other constituents being present in such large proportions as to prevent the molten metal from sinking down and forming a layer at the bottom, the charcoal lays hold of the oxygen of the silica, and the silicon enters into combination with the copper. Here are specimens containing 2 per cent. of silicon; the compound is very tough, can be cast, and cast perfectly. If we have more silicon than this present, we get a white, brittle, good for nothing metal.

COLMATION.

By J. P. FRIZELL, C. E.

Readers who have a fancy for examining the reports of the United States Engineer Department, have doubtless noticed in the volume for 1869, certain communications addressed to the Secretary of War by Gen. B. S. Roberts, suggesting a plan for ameliorating the condition of the Lower Mississippi Valley.

This plan, stated in language rather more figurative and elevated than is usually looked for in the discussion of a purely technical subject, amounted to this:—

He would draw off the flood waters of the river through suitable sluices and weirs in the embankments, and allow them to deposit their sediment upon the low grounds subject to overflow. He looked for several advantages from the adoption of this plan; mainly the elevation of the swampy grounds to such a height as to insure a suitable drainage; incidentally the improvement of navigation over the bar at the mouth of the river, consequent upon the diminished amount of sediment. He also proposed the introduction of water from the great lakes to raise the low-water stage of the river. The same volume contains a report upon the subject from Gen. A. A. Humphreys, the present chief of the engineer department, to whom the paper was referred. He details the result of a computation based upon the quantity of sediment contained in the flood waters of the Missisippi River, as ascertained in the course of the Delta Survey, showing that, under the most favorable suppositions as to duration of floods and quantity of sediment, it would require 150 years to raise the St. Francis Bottom, a region 6,000 square miles in extent, one foot. He concludes with the observation: "Having thus shown the impracticability of attaining the ends proposed by Gen. Roberts, I trust I may be excused from presenting a view of the cost necessary to carry out his plans."

The application of this system to the entire alluvial region would, so far as its cultivation is concerned, amount, as Gen. Humphreys observes, to a restoration of the country to its normal condition. The levees would be of little use if the country was subjected to inundation at every flood. It by no means follows, however, that the system could not be applied with advantage to less extended districts. In such application the arrangement suggested by common foresight would be, to allow the water to flow, with a very low velocity, over the ground to be benefited; every one familiar with the subject knows how rapidly deposits accumulate under such conditions.

In closing an island chute, the most approved method is to build a low dam across the upper or lower end, preferably the lower, allowing the water to flow over it, thus checking the velocity and leading to a rapid accumulation of deposit. The height of the dam is increased as the shoaling progresses. At first the channel receives the coarse material rolling or sliding on the bottom. As the dam is raised and the velocity diminished it takes only the fine material held in suspension. I remember, when engaged upon the Des Moines Rapids Steamboat Canal on the Missisippi River, that a cofferdam for one of the locks was flooded in the early part of the season, and remained so nearly all summer, the water flowing 2 or 3 ft. deep over the upstream wall of the dam, and, of course, taking a very low velocity within the enclosed space. When the dam was pumped out, there was a deposit of fully one foot in depth over the greater part of the bottom.

The entire Mississippi delta consists of material deposited by running waters. It is but natural to suppose that some artificial control might be advantageously exercised over an agency capable of such stupendous results.

It is not the purpose of this article, however, to advocate or oppose the views put forth by Gen. Roberts. The really noteworthy feature of the correspondence alluded to, is, that both parties treat the subject upon purely speculative grounds. Gen. Roberts appears to suppose himself the inventor of the system, and Gen. Humphreys opposes the project by theoretical calculations and reference to other theoretical calculations contained in his book. The discussion is incomplete, inasmuch as neither party cites any existing application of these principles. In discussing so important a matter, it is always proper to inquire as to the past experience of mankind. This is what I propose in what follows.

The process of raising the level of lands by artificially distributed alluvion, is designated in the French language by the word *colmatage*, in German by *colmationen*. I have not met with any English equivalent of these terms, probably because the practice does not exist in English-speaking countries. We may, perhaps, following a natural analogy, introduce the word "colmation," forming the caption of this paper.

I take the following general description of the process, as practised in France, from Buffon:*

"It now remains to speak of *colmatage*, which is at once the most simple, the most powerful, and the most economical of the processes of drainage, especially upon swampy bottoms. The necessary conditions, however, are by no means everywhere present; it is for this reason that the process has thus far been restricted to a small number of localities, where it has been employed with very great advantage.

"Colmation is nothing more than filling, successively effected by means of artificially distributed alluvion, and where a sufficiently abundant volume of turbid water is available, it is attended with results generally surpassing expectation. We shall see in the following section, in treating of irrigation, that *limonage*, or the employment of winter waters, with the simple aim of fertilizing, without seeking to change the level, is a very energetic operation, in the sense that, if we compute in cubic metres the contents of the lightest layer deposited by ordinary water, upon the extent of a hectare, we shall have a considerable result, which well illustrates the effects of this potent amelioration.

"When considerable depths are to be

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*Cours d'agriculture et d'hydraulique agricole. Paris, 1855. V. 2, p. 261.

covered, the colmation of marshes and swampy bottoms may profitably employ torrential waters, drifting gravel and pebbles.

"To attain the best results, it is in the order of things that we should commence to fill the deeper parts with coarse materials, very permeable, in order to imitate as far as possible the march of nature in the formation of alluvions, which are always the best agricultural grounds. If we have no torrential waters at our disposal, from which to extract deposits of this nature, we must content ourselves with the employment of those which deposit only mud or sand, and grounds formed to a certain depth with these latter elements, are always of high price, as proper for all sorts of cultivation.

"The processes employed for colmation are extremely simple; they consist in opening upon the shore of a rapid stream, subject to great floods, a species of cuts, called *epanchoirs*, by means of which volumes of water, approximately regulated, are directed, by special canals, upon the bottoms to be raised. The waters retained and becoming stagnant upon the bottoms, then deposit the sediment held in suspension; and, some time after their introduction, they are carefully drawn off, partially or totally pure, to be replaced by a fresh supply. The rapidity of the process depends upon the percentage of suspended matter and the frequency of renewal.

"The mechanism of the operation is thus very simple; it consists solely in the introduction of turbid waters by the aid of feeders, of declivity as near as possible equal to that of the supplying watercourse, then in a slow and superficial system of overflow, withdrawing the water freed as far as possible from sediment. This latter flow takes place usually by the aid of wooden weirs, roughly constructed, the height of which may be successively diminished. Dams provided with stop-plank are most convenient. The essentially temporary character of these structures enables us to avoid masonry. In most cases structures of rough wood are found to answer the purpose.

"A great extent of shallow ponds and low levels or salt marsh, bordering upon the Mediterranean, in the departments of the Ande, of the Herault, and the mouths of the Rhone, have been colmated in this manner, and are to-day meadows of the first quality; others are susceptible of the same improvement.

"An intelligent use of waters very rich in sedimentary matters, like those, for instance, of the Ande, the Herault, the Orbe, the Durance, etc., readily leads to a deposit of 15 or 20 centimetres (6 or 8 in.) in a season. * * *

"The waters of the Durance are peculiarly proper for colmation. It is a well established fact that the plains of Caraillon and others, which are abundantly overflowed by these waters, nearly always turbid, are successively raised; but excellent operations of colmation, properly so called, are now made by conducting the waters of the canals of the Durance, notably those of the territory of Avignon, upon the arid and gravelly plains, which, by a defect opposed to that presented in marshes, are equally sterile.

"Enclosures of an area proportioned to the disposable volume of water, being formed by low dikes, as if for simple irrigation; a slow and successive overflow favorable to sedimentation,—such is the method employed for this artificial creation of soil suitable for gardening and all improved processes of cultivation. In this case the materials brought into use being but earthy substance, without mixture of gravel or pebbles, the velocity being moderated in the canals of supply, which were constructed originally for simple irrigation, they obtain ordinarily a deposit of 3 to 5 centimetres (1 or 2 in.) per season; this, however, is a very gratifying result considering the increase of value; that is to say, considering the possibility of creating, in two or three years, an additional value of more than 1,000 francs per hectare upon strands or wastes formerly almost worthless. Frequent reference is made to the operations of colmation, executed upon these principles, in the vicinity of Avignon, by M. Thomas, a rich manufacturer and proprietor, who has already acquired in this manner a great extent of excellent soil.

"The operation of colmation should therefore be indicated, among the studies of the hydraulic engineer, as one of the most efficacious methods of applying the action of water to the improvement of agriculture."

It is in Italy, however, that this system has attained its greatest development and accomplished its grandest results. I take the following facts mainly from Hagen,* who appears to have studied this subject with great care.

The Chiana valley is an exceedingly level

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* Wasserbaukunst, 1st part, vol. 1, p. 355.

tract, some 30 miles in length, uniting the water systems of the Arno and the Tiber. Ancient writers affirm that the Arno once separated itself into two parts at the northern extremity of this valley, near Arezzo, one branch flowing southward, through the valley, to the Tiber, the other pursuing its present course, thus forming a navigable channel between Rome and Florence.[*] This is, however, a debated question among hydraulicians. Tacitus[†] relates that a project was introduced into the senate to separate the Clanis (now Chiana) from the Tiber, and turn it into the Arno, in order to moderate the floods of the former river, but that it was given up at the remonstrance of the residents of Florence. Later, however, though at what date is not clear, the separation was actually accomplished, and the waters of the Chiana were turned into the Arno. It appears, moreover, that the residents of the Arno valley, to protect themselves, also built a dam, about 40 ft. high, across the extremity of the Chiana valley. By these works the whole valley of the Chiana was reduced to an utterly uninhabitable condition. Its malariousness became a proverb in Italian literature, and when Dante aad other writers would stimulate the imaginations of their readers to conceive of a very pestilent place, they would compare it to the Chiana valley.

During the reign of the Medici, public attention was strongly directed to this unfortunate region. A map of the valley was prepared by direction of Julius of Medici (later Clemens VII.), in the year 1551. Hagen gives a copy of this map upon a reduced scale, from which it appears that the dam on the Arno side had prevailed over the other, the summit of the valley being, apparently, near the former. Torricelli, who studied this case, reported that the only available method of improvement would consist in raising the ground by sedimentary deposits, the feasibility of which process had, as it is presumed, been already pointed out by nature.

No action was taken, however, till the latter part of the last century, when the work was undertaken in accordance with a project prepared by Fossombroni.[‡] The former condition had, however, materially changed.

Since 1551 the ground had been raised in some places 37 ft. (Prussian). The details of Fossombroni's plan, by which it was expected to raise the level of the valley so that its drainage could be effected through the sluices of the dam at Arezzo, were as follows:

The small streams leading into the Chiana valley were provided with dikes. Embanked canals conveyed the water through the districts to be raised, where it was received in basins formed by low dikes. These basins usually had an area 100 to 300 times the square of the breadth of the river furnishing the supply. Often, several of these basins lay in succession, the water flowing from one to the other. The waste-ways and weirs consisted of depressions in the embankments, protected by fascines.

Ordinarily the dikes were raised to full height, that is, some 2½ ft. above the required level of the ground. The lower grounds, hower, were raised by successive stages. It was, in some cases, found necessary to divide the basins by cross dikes, to moderate the force of the waves. Narrow sluices of timber were provided, through which the water could be drawn off, when freed from its sediment, into canals at a lower level. These sluices were closed by stop plank which were successively removed, thus drawing the water always from the surface. This work was carried on directly by the Government. In 1823 it had progressed so far that the malarious character of the valley had entirely disappeared, and extensive settlements had been formed. There remained, at that time, about 160 square English miles to be reclaimed. Of the original area of the morass I can find no statement.

The streams made use of in this work, being of a torrential character, were better suited to this purpose than the Mississippi in one respect, viz., containing a larger percentage of sediment. In another respect they were less suitable; the duration of the floods never exceeding three days.

Other similar works have been executed in Italy inferior in extent to this, viz., the Pontine Marshes between Rome and Naples, and the Bonificamenta of the Maremma, where it is said that an area of 40 square miles has been covered with a deposit of earth 2 ft. in thickness.

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[*] Extrait des recherches sur le systeme hydraulique de l'Italie par M. de Provy. Annales des Ponts et Chaussées. 1834. II. p. 384.

[†] Annalium, liber i.

[‡] Memoire idraulico storiche sopra la valdi Chiana, in the Raccolta d'autori Italiana che trattano del moto dell' acque, 1789.

ON THE MANUFACTURE OF STEEL.

From "The Engineer."

At a recent meeting of the Society of Arts, Sir Francis Charles Knowles read a paper on the "Conversion of Cast Iron into Steel," and the exhaustive and suggestive nature of this paper, as well as the discussion which it induced, are such as to make us feel that a *resumè* of the important question thus investigated and analyzed will be acceptable to many of our readers. Indeed, the subject in its broadest and fullest sense, viz., the means of converting iron into steel, is one which, like good wine, requires no bush. It is of the first importance to the nation, whether looked upon merely from a commercial point of view, as giving us the power of being the great manufacturers for the world, or in the higher and more recondite sense of enabling us through the researches of science to avoid waste in the development and utilization of the great natural, mineral, and other resources placed at our disposal.

It seems desirable for the purposes of the present article to take the questions in the order in which they are treated by Sir Francis, and to comment upon them and his remarks as we proceed, reserving the discussion which followed, with the expression of our own opinions for the final summing up. We do not understand from the paper before us that the process advocated by Sir Francis has been actually tried, even in experiment, and we must confess that the way in which he uses the present tense through a great portion of his paper is somewhat puzzling, if not disingenuous; for, although, of course, the Heaton process is sufficiently well known, it does not in many ways exactly correspond with that now brought forward, and whilst Sir Francis says that "the finery or converter is made of pieces of cast metal so constructed that the tuyeres may form one piece with the casting itself—in fact, they are bored out of the solid casting itself, and the apertures are countersunk to meet them at the level of the hearth, etc."—we fail, nevertheless, to gather from the general context of the paper, or any definitely recorded results given, that such a finery or converter has actually been made and tried, and hence that both the author in explaining, and we ourselves in examining, the process, are dealing with possible probability rather than with ascertained fact. However, on this point we are indisposed to take exception, not that we think from what we have read that such exception is not a just one, but because we are desirous that, if the theories propounded have not as yet been proved, no words of ours may in any way stand in the way of their thorough investigation by practical experiment.

The objects proposed to himself by our author are, broadly speaking and in his own words, "the refining or purification of cast iron from sulphur and phosphorus, and its conversion into iron or steel of various qualities, according to the nature of the metal treated, with an increased yield of malleable iron or steel per ton of metal." And he goes on to say that the means adopted are—here again is a case of the present tense:—(1) "The separation, as far as possible, of the heating process from the chemical process. (2) The securing of a highly basic scoria, or cinder, of not exceeding 30 per cent, of silica, by means of finery and converting furnace in which that acid is not present. (3) The employment of caustic soda, in conjunction with pure and rich oxide of iron, in the elimination of the sulphur and of the phosphorus. (4) Where pure cast iron is treated, and superior steel is to be produced, the use of nitrate of soda, of permanganate of soda."

It is evident that to carry out any of the above processes, and to obtain any of the proposed results, heat is necessary; and this it is intended should be produced by the complete combustion of gases rich in carbonic oxide gas combined with air heated to 500 deg. Cent. in due porportions; and to this end, when the metal is melted in a cupola with either dense coke or anthracite coal, the resulting gases are collected and utilized by freeing them from carbonic acid and feeding them with pure carbonic oxide gas until a compound be obtained consisting of 70 to 80 per cent. of carbonic oxide gas and 30 to 20 per cent. of nitrogen. From this gas, which may be slightly altered in composition, a heat in combustion of from 2,500 deg. Cent. to 2,979 deg Cent., is obtainable, and on its being mixed in the condenser with hot air in such proportions as to insure the production by combustion of only carbonic acid gas and nitrogen, without excess of air, it is blown, according to Sir Francis Knowles, "into the body of the metal bath by appropriate apertures at the level of the hearth or sole, giving, therefore, a neutral flame, while the carbonic acid gas and the nitrogen rising from below with force in all directions, and aided by the natural lightness of the hotter metal, stir, agitate, and mix the particles of the metal, and so bring them all successively into contact with the re-agents employed, and with each other, doing in fact the work of the puddler." So far so good; but one of the most remarkable features of the new process follows next, for it is further proposed that the carbonic acid gas that is thus formed and the nitrogen which quits the surface of the ball, at say 2,150 deg. Cent., shall be passed through a kiln holding anthracite coal or coke, when the gas will take up a second equivalent of carbon; and one volume of it will yield two volumes of carbonic oxide, which absorbs about 2,400 units of heat per $2\frac{1}{5}$ lbs. of weight, the nitrogen remaining unaltered; and if, after a second combustion, this conversion of carbonic acid into carbonic oxide be repeated, the proportion of carbonic oxide to nitrogen will fall to 39.71 per cent., and so on in a decreasing ratio, until 34 per cent., the proportion in the cupola gas, is reached. The carbonic acid is thus acting as a carrier of the fuel from the retort of anthracite coal or coke to its destination, and the converted gases may be used first to heat the generating retorts and then passed under the boilers, which, according to Sir F. C. Knowles, ought, with good management, to be heated without any other fuel.

We now come to the construction of the finery itself, which, as has been before stated, is made of cast iron, the tuyeres being bored out of the casting itself, and the whole bound together by an exterior jacket of boiler plate, so that in case of an accidental fracture there may be no danger from the access of water to the molten metal, the whole converter being inclosed in a tank through which are passed currents of cold water to prevent fusion of the sole or walls of the finery.

For the lining of this, a basic paste is formed of protoxide of iron, or of manganese, of naxos emery, or of bauxite, a silicate of aluminum, strongly recommended by Dr. Siemens as fettling for his rotary furnace, and caustic soda in small quantity. This paste is laid on in thin layers, which, when gently dried, are successively reduced to a state of incipient fusion by the flames of the gases in such a manner that the particles may cohere and form a species of semi-enamel or glazing. The furnace is then complete and ready for operation. The next points for consideration are the effects of the reagents—caustic soda and the oxides of iron and manganese, which, as entirely distinct questions, we reserve for the present. We have stated enough to show what the general nature of the scheme is, and that it claims much about which opinions will differ materially.

THE STABILITY OF IRON STRUCTURES.

By W. MATTIEU WILLIAMS, F. R. A. S., F. C. S.

From "Iron."

A great deal has been written and spoken concerning the molecular changes produced in iron by vibration, and many instances are cited of iron that has shown a crystalline fracture after long exposure to vibratory disturbance. But those who theorize upon the so called molecular changes due to such action, base all their conclusions on a few exceptional facts, and apparently forget the multitude of other facts which contradict their theory. Ordinary experience shows that good iron remains fibrous throughout its substance after years, and even centuries, of considerable vibratory wear and tear. This broad general fact throws much suspicion on the isolated cases of crystalline structure attributed to vibration. If vibration is a true cause of crystalline structure, then crystalline structure should follow as an invariable consequence of vibration. This is certainly not the case, and therefore where the crystalline structure has been occasionally found we should look for another cause. This, I think, is not difficult to find, viz., in the original bad iron. It is no reply to this to point to the fact that one part of the piece of iron in question was fibrous, and the other portion that is supposed to have suffered, or really may have suffered more vibration, was crystalline, because, as every practical iron-worker knows, we may find fibrous and crystalline iron, not merely in different fractures of the same bar, but even in different portions of the same fracture. Inferior, ill-worked iron is especially liable to such irregularities of structure. The theory that localized crystalline structure is produced by vibratory action may sometimes be very convenient for contractors, but I doubt whether it has any reliable foundation in fact.

The above remarks must not be understood as implying that vibratory shocks may not weaken iron. There are many incontestable facts which prove that a vibratory shock, if sufficiently violent, certainly does affect such weakening. I need only refer again to the trials of armor bolts by the falling test, described in my last paper. Here we had a definite force applied as a sudden shock, a weight of one ton falling 30 ft. The first blow is resisted by the best iron, the second blow also, likewise the third; but, on applying the same amount of force in the same manner a fourth time, the iron yields, showing that the previous shocks had weakened it, and rendered it unable to resist a blow that it was previously able to bear.

But was this weakening due to the development of crystalline structure? Certainly not. The alteration of structure indicated by the best iron was rather in the opposite direction. The "distress" exhibited after the first blow, and more and more obviously displayed after the second and third, presented the appearance of a dragging or stretching out of the fibres, a sort of exaggeration of the normal fibrous structure of the iron. In those parts where the extension and consequent reduction of diameter was the greatest, the fibrous structure of the iron was to a certain extent visible on the skin of the metal, and the final fracture of the best samples had a brush-like character, due to this dragging out or exaggeration of fibre. These appearances are also observable when the best iron is broken by a gradually applied tensile strain, and may be studied in some beautiful samples of fracture that are preserved by Mr. Fairbairn.

It is true that in these cases the strain has been exerted only in one direction, and doubtless the effect would have been different had its direction varied, but what would be the extent of this difference? Merely, I suspect, to neutralize the dragging out or exaggeration of fibre, but not to substitute for this another and very different action—viz., the development of crystalline structure. I do not at all question the conclusion that a long continuance of small vibratory shocks may probably weaken iron or steel by gradually effecting a similar "distress" to that so plainly exhibited and suddenly produced by the violent shock of the falling test, but do maintain that we have no sufficient or even approximately sufficient evidence in support of the theory that vibration can convert fibrous into what is called crystalline iron.

A further and full experimental investigation of this subject is imperatively demanded, and may readily be made. Cut a good plate or bar into at least twenty equal pieces; shuffle them well, then take ten and ten. Let the first ten be laid aside in a quiet place, and the other be exposed to continuous and sharp vibration for a year or two. Attaching them to a tilt-hammer regularly used for shingling the faggots of blistered steel, and making about 300 strokes per minute, would do very well for this purpose. Then let each two be tested for tenacity and their average tenacity compared.

I say at least twenty, because all wrought iron is more or less variable in cohesive power at different parts of the same plate or bar, and thus the more numerous the trials and broader the average, the more reliable the result; and "shuffled," because if one set were all middle pieces, and the other all side or end pieces of the plate or bar, the trial would be delusive.

There is another and very curious question connected with this subject that also demands similar investigation, its practical and philosophical interest being considerable. It is whether iron and other inanimate substances are susceptible of becoming weakened by "fatigue," and of recovering in some measure by repose. Many may smile at the bare suggestion of such a question, but it is not so ridiculous as it may appear. Intelligent workmen, whose daily experience constitutes the broadest of experimental data, assert that the tilt-hammers of steel works, which work with the greatest rapidity, rapidly give way near the axis unless they are allowed intervals of rest. I have never had an opportunity of verifying this or any other similar cases, but, nevertheless, see no good reason for discrediting it, nor any great difficulty in understanding how it may occur. When iron, steel, or any other elastic substance is subjected to a gradually increasing strain, the first indication of distress is an elastic extension, that is an extension which is partly or wholly recovered when the straining force is removed. Now let us suppose that the total breaking force in any such case is $=a+b$, where a is the amount of force sufficient to produce an elongation recoverable by elasticity; it is evident that when the substance is in this condition, the strain by which it may be broken is a smaller force than when, in its normal state, it is b instead of $a+b$, or otherwise it is weaker in this condition than when at rest. If, then, the recovery from the state of elastic strain is not instantaneous, but demands some time, a period of rest equal to that time is demanded, in order that the strained material may recover from its fatigue. The question is thus reduced to whether complete recovery by elasticity is instantaneous or occupies some time, and how great is that time? Also whether this period of recovery varies with different substances? There can, I think, be little doubt that an appreciable time is demanded, that the length of that time varies considerably, and is intimately connected with that internal friction which has been described as molecular viscosity.

The effect of temperature on the stability of iron and steel has been recently treated rather fully in iron. Putting all the relible experiments and other data together, I think I may venture to generalize to the extent of saying that lowering of the temperature of iron or steel affects its powers of mechanical resistance in nearly the same manner as the addition of carbon, silicon, or phosphorus, the resemblance being nearest to the action of phosphorus.

If this is correct, then the effect of intense cold on iron or steel will be to increase its brittleness when subject to a vibratory shock, while it increases its tenacity as tested by a gradually applied and steadily increasing strain, and the effect of raising its temperature is the converse of this, *i. e.*, a given sample of iron will be less liable to fracture by mere vibration when hot than when cold, and weaker when tested by a steady pull. I may also venture to express my belief that the presence of sulphur, within certain limits, tends to mask this difference, but not to fully counteract it, while phosphorus, silicon, and carbon materially exaggerate it. Or, in other words, sulphur diminishes the differences due to a given variation of temperature, while phosphorus, silicon, and carbon increase it.

Those who have studied this subject and are disposed to prosecute it further, will, I think, find in the above inductions an explanation and reconciliation of most of the apparent contradictions which recorded experiments present.

ARCHITECTURE IN THE ELEVENTH CENTURY.*

By J. H. PARKER, C. B.

From "The Architect."

In two very interesting old churches that the Institute visited in the course of the year 1872—St. Mary's, Guildford, and St. Michael's, Southampton—the same remarkable feature was observed which had previously escaped observation—the remains of a small cruciform church enclosed and incorporated in a much larger church of a later period. This sort of economy is very usual in old parish churches, the people preserved as much as they could of the small old church when a larger one was required. The question naturally arose as to what period these two old churches belonged; I considered them as more probably of the first half of the eleventh century than of any earlier period.

In the account that I wrote of St. Mary's, Guildford, I stated that opinion; and gave, as my reason for thinking so, that the generality of the so-called Anglo-Saxon buildings are of the eleventh century, and that there is a wide distinction between those of the first half and those of the second half of that century; during the

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* From the last number of the "Transactions of the Archæological Institute."

second half we know that the Norman style came in, but it was not imported as a complete style from Normandy, it was gradually developed after the time of the Conquest, both in England and Normandy (which had then become only one of the provinces of the same kingdom), and the style is properly called by the French antiquaries the *Anglo-Norman* style. Normandy was a little in advance of England as regards architecture at the time of the Conquest, but not much; the Anglo-Saxon buildings had greatly improved in construction before the time of the Conquest, and the Norman style had been introduced at Westminster by Edward the Confessor. During the reign of that king we have also the dated example of Deerhurst, A. D. 1053, the construction and decorations of which are very much in advance of the Anglo-Saxon towers of Lincolnshire and the Dane's land, which belong chiefly to the reign of Cnut, or Canute the Dane. These towers are more common than people are generally aware of; Mr. Matthew Bloxam and myself made out and published a list of a hundred of them twenty or thirty years ago, and many more have been observed since that time by Sir Charles Anderson and others. They belong to the churches recorded to have been built by order of Canute on the sites where churches had been burnt by his father or himself during the wars which ended in the settlement of the Danes on the eastern side of England. All this is a very old story, but it seems necessary to recapitulate it, and this brings us clearly to the first half of the eleventh century. My own conviction is that the churches that had been burnt by the Danes were wooden churches, and that the churches built in their places were of "stone and lime," as is recorded in one instance certainly, that of Assandun (Ashington, in Essex). Stone buildings were then becoming more the fashion, there always had been a few, but they were the exception; the general custom was to build of wood as most economical, the country being to a great extent covered with forests.

The question now disputed is, whether these churches were built by persons accustomed to build of cut stone, and were only a continuation of the debased Roman style of building and of construction, or were built by persons accustomed to build of wood only, and are rude and clumsy imitations of Roman remains?

In all probability the greater part of the buildings recorded to have been built of stone in the tenth century, were built of rough stone or rubble—walling only, and not of cut stone. The few buildings that were of cut stone were so very remarkable that they were always recorded and eulogized to a degree that seemed absurd afterwards, but they were so superior to anything the writers had then seen, that they made the most magniloquent description of them. We all know the description in Latin verse of Winchester Cathedral, as built in 980, and yet we also know that a century afterwards it was swept away as not worth preserving; even in the building erected in its place on a new site the construction of the early part is very rude; there is a great waste of material and of labor; the joints between the stones are extremely wide, and the contrast between this construction and the later work of the twelfth century, after the fall of the central tower, is one of our best guides to the distinction between the construction of the eleventh and of the twelfth centuries. If even quite at the end of the eleventh century the masonry was not further advanced than that, we may well imagine how rude the masonry must have been three generations before that period. Those three generations were a time of rapid progress in the art of building, and this therefore carries us back to the rude construction of those Anglo-Saxon towers, and to the herringbone work in the walls, which is one of the characteristics of that period. All the dated examples of herringbone work that I know of are of the first half of the eleventh century, and I know of several of that period in various parts of the world. There is one in Rome, dated by an inscription upon it (the side wall of St. Pudentiana), another in Normandy, dated historically, that of the castle of Plessis, and there are others in England also.

It has long been seen and acknowledged that very often the only mode of distinguishing between the construction of the eleventh century and that of the twelfth is by the thickness of the mortar between the joints of the stones. This is well exemplified in the two great abbey churches of Caen as well as in Winchester Cathedral. The construction of the first half of the eleventh century is so bad that it is evidently an imitation of the much better construction of an earlier period. The small old church at Bradford, in Wiltshire, is just one that proves my point: the construction is extremely good, such as we do not find anywhere in England or France in the tenth or eleventh century. The joints are as fine as possible, which they never are anywhere in the eleventh century. If the Roman art of building was not lost at least for one generation of men, how does it happen that the art of vaulting (a very important part of Roman architecture) was entirely lost, and no builder ventured to throw a vault over a space of 20 ft. wide before the middle of the twelfth century? The general use of wooden buildings in the period between the Roman empire and the twelfth century is the only manner of explaining this. Wide-jointed masonry is always one proof of bad and clumsy construction. The Anglo-Saxon towers of the first half of the eleventh century are evidently the work of carpenters only, of men not accustomed to build of cut stone. No mason would think of placing long pieces of stone vertically up the angles of a tower and make a framework to bind it together. Jarrow and Monks Wearmouth support my view. The monk of Durham of the time of William I. and II. distinctly says that these churches were in ruins, and overgrown with shrubs, when they were restored by his brother-monks, and the existing remains agree perfectly with this history.

Bradford stands in the middle of some of the best stone quarries in England; it was therefore cheaper to build of stone there in the eighth century. But the greater part of the country was covered with forests, and therefore wood was the natural material to use in most places. This building was exceptional. My much-lamented friend, M. de Caumont, of Caen, was certainly one of the best, if not the best archæologist of France, for the last 30 years. He was the first to introduce the principles, though not the details, of Rickman's system into France, about 1830; and to form an Archæological Society, to make excursions to objects of interest in all parts of France, and to compare one province with another. He and his companions found, by long and frequent observation, that the very distinct provincial character of the different parts of ancient Gaul can all be traced to some one Roman building, which has served as a type for that district, when the revival of building in stone took place. The best known instance of this is the diocese of Lyons, where fluted columns, in evident imitation of their Roman type, are used in the cathedral in a construction of the thirteenth century, and the same thing occurs in many other churches of that diocese.

For many years past I have been hunting for buildings of the tenth century with very little success. It is matter of history that some stone buildings were erected at that time, but there is very little construction of that period remaining in any of them. I have been a member of the Société Archæologique de France for the last 30 years, and made many similar researches with them. M. de Caumont himself went with some friends to the sites of all the castles of the Norman barons who came over to England with William the Conqueror, to search for examples of the masonry of that period. To his great surprise and annoyance, he could find no masonry at all in any one of them before the time of the Conquest. He found magnificent earthworks in all of them, but no masonry; showing that the castles of the first half of the eleventh century were of earthwork and wood only in Normandy, where, of all other places, we should have expected them to have been of stone. The Normans were certainly not behind the rest of Europe in the art of building. Even in Italy it is very difficult to find any masonry of the tenth century now remaining. In Rome the only building of that century is the sacristy of the church of Sta. Croce, in Gerusalemme, which is dated by an inscription upon it. The construction of this is as bad as it could be; a worse construction would not have stood at all. Of the first half of the eleventh century in Rome, the only dated example is the wall of the church of St. Pudentiana, and the construction of that is of herring-bone work. It happens also, that all the other dated examples of that construction that I know of, are also of the eleventh century, but such simple construction may be of any period. In the celebrated example of St. Remi, at Rheims, the construction of the walls is of the character of the first half of the eleventh century, but all the ornamentation has been added or entirely altered in the twelfth. Some, if not all, of the rich capitals of the twelfth century are made of stucco, fixed upon the plain and rude early stone capitals of the eleventh. When I went there some years since, with M. Viollet-le-Duc, who was then in charge of some restorations in that church, we saw one of the stucco capitals that had been broken, and inside of it the early stone capital. About the same time I saw the same thing at Jumièges, in Normandy, with M. Bouet, the excellent French artist who usually accompanied me in France, and he made a drawing of it, which I put into the fifth edition of the "Glossary of Architecture," in the description of the plates, which happened to be then in the press.

In the west front of Lincoln Cathedral the capitals of Bishop Alexander, of the twelfth century, are inserted in the early walls of Remigius. This I detected by the fine jointing of the masonry in the insertions, and the wide-jointed masonry of the early work. I had previously sent Mr. Jewitt to make me a drawing of one of the capitals of Remigius, of which there are a few remaining; but he drew me one of Alexander by mistake; and as he did not draw the jointing of the masonry (for no artist ever thinks of doing so), I did not at first discover the mistake, but saw it at once in a subsequent visit.

The well-known passage from Radulphus (Radolf or Ralph) Glaber, mentioning that "the world seemed to be putting on a new white robe," at the beginning of the eleventh century, which he witnessed, certainly indicates a considerable change at that time, a revival of building in stone, just as another incidental notice in William of Malmesbury, that the buildings of Roger, Bishop of Salisbury, in the beginning of the twelfth century, were so well built that it appeared as if each wall was made of a single stone, indicates that fine-jointed masonry was then first introduced into England as into Normandy. The Norman style is properly called by Viollet-le-Duc the "Anglo-Norman style." It was not introduced as a complete style by the Normans at the Conquest, but was gradually developed in all the provinces of the Anglo-Norman kingdom simultaneously: the variations between England and Normandy amount to no more than provincialisms. The Norman keep of the earliest character that we have either in England or in Normandy is the one built at Malling, in Kent, by Gundulph, in the early part of the reign of William the Conqueror. His invention exactly fitted the wants of the Normans settled in England, and therefore that type was rapidly followed and soon spread all over England and then to Ireland and the Continent. We find Norman keeps everywhere, even in Italy. I am fully convinced, both from my own experience and long observation, and from that of others whom I have known to be careful observers, that buildings of the tenth century are extremely rare, and that on the other hand the first half of the eleventh century was a great building era; and we have many buildings of that period remaining, although that fact has been usually overlooked, and those buildings are commonly supposed to be either much earlier or later. I believe that to be the case with the two rude small and early cruciform churches visited by the Institute in the summer of 1872—St. Mary's, Guildford, and St. Michael's, Southampton—both very much of the same character, and each enclosed in a much larger church of a later period. The construction is so rude, that it might be of any period when the art of building was in its infancy; but that is exactly what appears to have been the case when the revival of stone building began. It is not debased Roman art, but a rude imitation of it.

Professor Willis, in his admirable history of the Cathedral of Canterbury and Winchester, does not say that we have any building of the tenth century remaining in either. Archæology has to do with existing remains: "the things that have been" belong to history only. At Winchester the present church was built on a new site, near the old one, not on the same foundations. At York, Professor Willis ridiculed the idea of Browne's history on the very point that Browne supposed the existing building to be the original one. It is possible that there may be some small remains of it in the foundations of the crypt, but it is difficult to make out any, though it is on the old site. At Ripon and at Hexham the old crypts exist, built of fragments of Roman buildings; but their character is quite peculiar, not in the least like the Anglo-Saxon buildings. I have published engravings of them. The church at Bradford, as I have said, is an exceptional case; the fine-jointed masonry proves it not to be of the eleventh century, nor of the tenth; it is most probably of the eighth; although I do not remember one of that period like it anywhere. Still, as a window of the twelfth century seems to be inserted in the old wall, and this wall is certainly not of the tenth or eleventh, I conclude that it must be of the eighth. Shallow sculpture was the fashion then, and the shallow arcade cut in the surface of the old wall may be of that period. I should be very glad if any learned friend would name any other building now existing of that period which corresponds with Bradford. I have spent several months in Aachen, and have drawings and photographs of the church or chapel there, and published a short account of Roman-Moutier and Lorsch, with engravings, in the "Archæologia." It is well known that very many of the legal documents of the latter half of the tenth century conclude with the words, "the end of the world being at hand;" and this general belief is likely to have had its influence on the buildings of that period, as it appears to me evident that it had. I do not know of three buildings of that period remaining in the west of Europe. We all know how the same buildings that are mentioned in grandiloquent terms by the Saxon writers are mentioned with contempt by the Normans a century after (more or less), and were often swept away as not worth preserving. At Soest I was once the means of saving a curious old church from destruction, which may possibly be called of that period; but from its construction I do not believe it to be so. The rules of archæological evidence are our safest guide to the date of a building. "The construction of the same period is always the same." In the only examples of that period that I know of, the construction is as bad as it well could be. This class of buildings is exactly what I mean by those of the first half of the eleventh century, or continuing rather later, perhaps from 1,000 to 1,080. The towers of this class in the lower tower of Lincoln we know to have been built after the time of the Norman Conquest. They are rather more advanced in construction than some of the others; they belong to the third generation of masons, after the revival of building in stone. The work of each generation of men may be traced by the construction and the architectural details of their buildings, from the the time of the kings of Rome, and of the re-building of the Temple of Solomon at Jerusalem, under King Ahaz, to our own days.

In the early period all the ornamentation was of wood and bronze; the wood has been burnt, and the bronze melted down, and we have only the rude massive stone walls of the original construction remaining; but these may be divided into three classes; as I have shown very distinctly in Rome, there is a change in each half century. Such changes are equally distinct in the Middle Ages in England, as is shown by the dates in my "Glossary of Architecture," the first work in which architectural details were ever dated by their historical types.

HYDRAULICS OF GREAT RIVERS.

From "Iron."

Three years ago M. J. J. Révy surveyed the estuary of La Plata and the two principal of the great rivers which form it. The work was executed at the instance of the Government of the Argentine Confederation, as a preliminary step to large engineering works then in contemplation. A work of this nature was certain to throw light on many hydraulic questions; and the methods of the survey, its results, and their application to problems partially settled, or till then wholly unsolved, have just been laid before the public in a manner rivalling in fulness but excelling in clearness the great streams surveyed. (The Parana, the Uruguay, and the La Plata Estuary. By J. Révy, Memb. Ins. C. E., Vienna, etc., etc. London: E. and F. N. Spon. 1874.)

The Parana, the principal tributary of the Plate, is a mighty river of great depth, and though traced for many hundred miles from its mouth, has never been found less than a mile in width. The Uruguay is over half a mile in its narrowest breadth; but both occasionally, especially in their lower courses, spread out much wider, with swamp and jungle-covered banks. On this account the use of levels, chains and theodolites was much restricted, and M. Révy, in the absence of even a single trained assistant, was forced to adopt new methods, as ingenious and effective as they were novel. Indeed, dealing with such vast masses of water and river-beds on such an enormous scale—the La Plata being at least 20 miles across at its narrowest width

—the old-established methods would have been of little use. A small steamer, the Aguila, with the necessary adjuncts, was placed at the disposal of M. Révy, and about the middle of January he sailed to survey the Parana. The river was then beginning to rise to the level which it retains, with little variation, during March, April and May. A base line was measured on the bank, and the gauge fixed. It showed a steady rise at about the rate of an inch in the 24 hours. M. Révy advises that the gauge should be put down whereever possible, even where there is no intention of taking a section. The first cross section was taken about 12 miles below San Rosario. The depth of water was not gauged in the usual way by means of marks on the sounding line, that having been found inaccurate, but the cord was drawn on deck, and measured with a tape. The steamer was managed so that it drifted with the same velocity as the current, and then the lead was lowered, and the soundings taken as if on a mill-pond, the exact line of section being indicated by the flag on the extreme end of the base line, and two on the line of section covering each other. From check operations these soundings were found accurate to the inch of depth. The determination of the current was effected by means of water meters, an improvement on the ship's log which, M. Révy says, gives superficial currents with great accuracy. With the deeper currents, however, the instrument failed him; but he was equal to the occasion, and, with a bar of iron replacing the wooden rod used for surface currents, and a simple but ingenious method of mooring it at the requisite depths, he had an instrument which never once failed him at any depth. Not only so, but he was enabled to integrate all the currents from surface to bottom in a vertical plane, and so find the absolute mean of all the different currents in a vertical line at the point of section. This improved instrument M. Révy names the "Current Integrator;" a still further improved form of it is described in the appendix. For the complete details of M. Révy's method, which are much too full for enumeration here, such of our readers as may be interested in the subject are referred to his book.

Indeed, the facts there recorded are so new and so numerous, and depend for full elucidation so much on the diagrams and figures, that we shall probably best accomplish our task by simply recapitulating a few of the leading results of this important survey. And first, as to the estuary La Plata. The River Plate is about 125 miles long, varying in breadth from 23 to 63 miles, and ranging at low water from 3 to 6 fathoms in depth. The original length of the estuary was about 325 miles, but 200 of these have been filled by the deposits brought down by the Parana, which, *pace* Dr. Cumming, will doubtless in time wholly fill up the La Plata; for why may not rivers like men be "immortal till their work is done"?

Of the Parana, M. Révy says it is practically unknown in Europe out of the hydrographic department of the British Admiralty. Ships are guided through the intricacies of its lower channel by native pilots, who never look on a chart, but, brought up on it from boyhood, know every tree on its banks, and every change of its shifting bars, and rarely meet with mishaps. The scenery in the lower reaches of the delta is described as very fine, the river gliding along without a ripple in the midst of stillness the most profound, and the banks gay and glowing with bright flowers amid a setting of dark green foliage. For some reason the margin of the river is scant or void of animal life, even birds, abundant a little inland, are scarce along its margin. About 270 miles up the Parana its left bank is bounded by a "bluff" about 200 ft. above the level of its waters, supplying an excellent section of the latest geological formation of the country.

The plain traversed by the Parana, bounded on the west and east by the Andes and the Atlantic, and south and north by the Straits of Magellan and the mountains of Brazil, is the largest tertiary basin in existence. The lower strata are sandstones of marine origin; regarding that of the upper, which is the land of the present day, geologists are not agreed. It is probably an estuary formation, and filled by the rivers which drained the land then above the sea level, and deposited in their embouchures the bodies of the animals that then flourished in its forests. These remains include those of the mastodon, cerodon, milodas, several stags, evidently contemporaneous with the great mammals the remains of which occur in similar superficial formations in Europe, immediately prior to the glacial epoch.

The upper portion of the Parana is

wholly unexplored, and about 700 miles above Corrientes, an immense fall, called "Guaira," puts an end to navigation. The river a little above the fall has still a width of two miles and a-half, and contains more water than all the rivers of Europe united; but this immense width is at once reduced to a narrow channel of about seventy yards, in which its waters break, in the words of an eye-witness, "with indescribable fury, not in a vertical line, but upon a plane inclined about 50 deg., forming a clear drop of about 20 yards measured vertically; the clouds produced by the concussion of the water against the walls of its granite channel and on the rocks which project in the middle of the current, forming columns of steam, which may be seen for several leagues, and in which numerous rainbows are visible. A continuous rain, produced by condensation, falls in the neighborhood; the noise of the cascade is heard 6 leagues distant, and close to it one believes the earth is trembling" And Domingo Platiño, sent, in 1863, by the Dictator of Paraguay, Carlos Lopez, to explore the Parana, and who, after much privation, reached as far as the Great Fall, says: "The thunder-like noise of the Fall could be heard at a distance of ten leagues, and within one league the noise was so great that it was difficult to hear one another; at the Fall itself it was impossible to distinguish any voice, all being drowned in the thunder of the terrific concussion of contending waves. It was not a vertical drop which caused the thundering noise, but the concussion of immense waves which broke upon vertical granite walls, narrowing the ordinary width of the Parana to about 70 metres; the difference between the upper and lower level may be about 20 metres." He adds, "it is reported that the settlements close to the Fall of Guaira had to be abandoned on account of the noise, which made the population deaf." The bulk of the volume of the Parana is derived from a great number of rivers and innumerable torrents rushing from the tropical mountain ranges of Brazil, its drainage area extending over many hundred thousand square miles, and it is probably the greatest river in the world.

The Uruguay was surveyed by the methods employed on its sister river. M. Révy characterizes it as at times a mighty stream, rivalling the Parana; at others, sinking into comparative insignificance. "The Parana is," he says, "a great river at all times, conveying an immense volume to the Atlantic, at its lowest condition never falling to 50 per cent. of its ordinary flood volume. The Uruguay is subject to frequent and remarkable fluctuations; during great floods it rivals the Parana, and one month later sinks to a small percentage of its former greatness. The Parana is the type of a truly great river; the Uruguay represents a mighty torrent of extraordinary dimensions."

The conclusions which M. Révy draws from his investigations are clear, philosophical, and highly important, while they have a direct and most useful bearing on our own noble river and its altered conditions depending on the great work which now confines its waters between Westminster and Blackfriars. The results of his survey, he contends, place the question beyond doubt that the accepted principles upon which hydraulic engineers based their arguments when the movement of water in open or confined channels had been under consideration, were at variance with those of nature. His observations, he maintains, disclosed and established the dependence between depths and currents; that at a given inclination surface currents are governed by depths alone, and are proportional to the latter. "The greatest current is at the surface, the smallest at the bottom; as the depth, however, increases, or the surface current becomes greater, so the difference between surface and bottom currents will be smaller and smaller, approaching equality, until in great depths and in strong surface currents they are substantially alike."

Finally, he observes: "The science of river engineering had been comparatively neglected. In no other branch had graver or more expensive blunders been committed. No doubt it was in a great measure guesswork—matter of opinion—reasoning upon the solid basis of observation having been at a discount. Rivers inundate vast tracts of land, and continue to do so, not because they have too much water, or that their depth is not great enough, but because we are too shallow to offer the proper remedy, which, in nine cases out of ten, it would be in our power to give, and under our control to accomplish. Channels of estuaries and harbors silt up, and then navigation becomes more and more difficult, not because the action of the sea is different to-day from what it was a century ago, but because we are, in the first place, more alive to alterations; and, in the next, because in many instances we had already aggravated the situation by desultory attempts at improvement.

There is hardly a more intricate problem than the consideration of currents, and their ultimate effect on the channels of an estuary; yet, with but few exceptions, 'improvements' are made without an attempt to trace the history of an estuary, much less the causes at operation; and we generously leave it to the next generation to reflect over and learn by our present mistakes."

SCIENTIFIC AND INDUSTRIAL EDUCATION IN THE UNITED STATES.*

From the "Albany Evening Journal."

A little more than two hundred years ago,—in England of the Round Head and Cavaliers—a voice was raised to propose that young men be instructed in branches bearing on the various national industries.

He who proposed this was a man of great genius—one of the true priests and prophets of his time. He foresaw and foretold many great modern inventions, and among them the steam engine. His brain helped to think out its principles — his hands helped to shape its groundwork. With pen and tongue he sought to promote the "new education"—but he had fallen on evil times. With Straffords and Lauds on one side and Hampdens and Cromwells on the other, there was but poor hearing for the industrial ideas of the Marquis of Worcester. Persecuted, maligned and a bankrupt, he died, and to all appearance his idea died with him. For two centuries afterward Oxford and Cambridge solemnly ground out the old scholastic product in the old scholastic way.

About 50 years ago a body of the best scholars and thinkers in England made another attempt. Their endeavor was to found an institution giving an education fitted to the needs of their land and time. They established the University of London. Never had a plan more brilliant advocates. Brougham, Sidney Smith and Macaulay spoke and wrote for it;—but their success was small. The institution was unsectarian, therefore the Church declared against it as "godless"—it gave instruction in modern learning as well as in ancient learning, and therefore the great body of solemn scholars declared it unsound. Some of its ideas and methods were new, and therefore a multitude of leaders of society declared it unsafe. The institution was kept down, and from that day to this has never taken the high place to which its plan and work entitled it.

About 30 years since, the greatest man who has ever stood in an American College Presidency made an effort in the same direction. Francis Wayland knew what there was of good in the old scholarship and was loyal to it, but he saw that new times made new demands, and he planned out and endeavored to work out a system of education which should meet these demands. All to no purpose. It was the old, old story—another great man, with his great idea, as Carlyle phrases it, "trampled under the hoofs of jackasses," or as Wayland himself phrased it more mildly, "nibbled to death by ducks."

Various minor attempts were made—some of them, like Eaton's noble effort at Troy, very fruitful—but no great general plan, no large institution was created worthy of the great interest involved.

About five years later, Mr. Lawrence, of Massachusetts, a thoughtful manufacturer, made another attempt. He saw the necessity of education bearing on the great industries of the country, and made to Harvard College what in those days was called a princely gift. Thus was founded the "Lawrence Scientific School" at Cambridge, and thus did industrial studies get their first foothold in a great university.

About five years later still, Mr. Sheffield, of Connecticut, also a thoughtful business man, recognized this great necessity. By a generous donation he founded the "Sheffield Scientific School" at Yale College, and thus

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* Extract from an address delivered before the State Agricultural Society at Albany, by Andrew D. White, President of Cornell University.

these studies got foothold at a second great university.

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(Speaking of practical instruction in our technical schools, President White continues.)

Indeed, I know of no more pressing national need in this country. Our land has more mechanical ingenuity in it than any other; but did you ever think of its wretched misdirection and waste for want of industrial education? If not, stroll through the national Patent Office. Look at a few facts. In one of our most important cities are engines for supplying that city with water—erected at vast expense. The whole amount was wasted. There is ingenuity in that vast machine, there is skill in it; but for want of education regarding certain principles involved, the whole thing is failure and waste.

Take another case. A few years since, with a small party of our fellow-citizens, I visited the West Indies in a national ship. She was a noble vessel and her engines had cost, it is said, nearly $800,000. The engines showed ingenuity; but they were so deficient in proper elements of construction that our voyage was prolonged until we were all given up as lost and had the honor to have our obituaries in the leading newspapers. The first voyage of those engines was the last. They were sold for old iron, and the sum lost on them alone was sufficient to endow the finest institution for mechanical engineering in the world. I might multiply examples of this sort; but this is enough to show what need exists for more careful training in the direction, and I pass to a kindred department.

CIVIL ENGINEERING.

Another great department, bearing on a multitude of industries, directly and indirectly, is civil engineering. Take one among the fields of its activity. We have in the United States about 70,000 miles of railway, and every year thousands of miles are added. I do not at all exaggerate when I say that millions on millions of dollars are lost every year by the employment of half-educated engineers. Proofs of this meet you on every side. Lines in wrong positions, bad grades and curves, tunnels cut and bridges built which might be avoided. All of us know the story.

But this is not all. Hardly a community which has not some story to tell of great losses entailed by bad engineering in other directions. Here it is the traffic of a great city street interrupted for a year because no engineer can be found able to make the calculations for a "skew-arch" bridge, a thing which any graduate of a well-equipped department of engineering can do; there it is a city subjected to enormous loss by the failure of its water-supply system, because the engineer employed made no calculation for the friction of water in the pipes; in another instance it is a whole district sickened by miasma, because a half-taught engineer was intrusted with its drainage. We must prepare men for better work, and for every dollar thus laid out we shall create or save thousands. Nay, we shall save lives as well as money. Mr. Baldwin Latham, in his recent book on Sanitary Engineering, and Dr. Beale, in his work on Disease Germs, show by statistics that a proper application of engineering to sewerage would save 100,000 lives yearly in Great Britain alone, and the same truth holds in this country.

ARCHITECTURE.

Wealth and public spirit—individual and municipal—are now erecting myriads of noble buildings in all parts of our country. The number of uneducated architects is very great—the number of thoroughly prepared architects is very small. Have you ever considered the waste attendant upon this? Every month you hear of some architectural failure that costs life and treasure. To-day it is a church floor which gives way and a multitude of children are taken from the ruins mangled and dead;—to morrow it is a whole city quarter swept away by fire, because some half-taught architects knew no other way of producing architectural effect than by piling up combustible ornaments on inaccessible roofs.

Nor is that all. Our people are laying out millions on millions in buildings which within 30 years—in the advance of taste and knowledge—will be eyesores and must come down. A building erected by a true architect will grow more beautiful for hundreds of years. A building erected by a sham architect will be an incubus in a quarter of a century. Men are beginning to see this, and we are endeavoring to prepare men thoroughly to know the best materials—to calculate their strength in construction and to combine material and construction according to everlasting laws, and not according to some pretty present fashion; and this is the purpose of our School of Architecture.

THE ARTS OF DESIGN.

The average visitor to an institution like that established in this State will often say something like this: "I can understand the value of your libraries—collections in Natural History, apparatus, models, shops and lecture rooms, but what use of your great draughting rooms?"

If you answer that drawing is taught in one for Civil Engineers; in another for Mechanical Engineers; in another for Architects; in another free hand drawing for all these together, he will say, "Why teach free hand drawing at all? That is rather artistic than industrial."

Is it? Look at a few recent facts. A few years since, the State of Massachusetts passed a law requiring free hand drawing to be provided for in the public school system throughout the State. The city of Boston did the same. State and city combined to call from the great English school for Industrial Art at South Kensington, Mr. Walter Smith at a salary of $5,000 to direct the schools of that city and State.

Mr. Smith has worked on and the result is that already this instruction has been admirably developed. Now, why has this been done? Has the State of Massachusetts, which we have always known as so thoughtful in its legislation and education, really fallen into mere dilettantism? Not at all. Look at a few more figures from the census.

In 1870 the product of Massachusetts in printed cottons was over $17,000,000, and her product of other goods into which the arts of design enter as a matter of first importance was doubtless even more. Massachusetts is thoughtful as ever. She sees that other States are overtaking her in manufactures so far as quantity and quality of material are concerned, but she determines to distance them by spreading throughout her borders a knowledge of the principles of beauty in design and skill in them. And she never did a wiser thing. It will tell on a multitude of industries. Why do we import such vast quantities of English, German and Danish glassware and pottery?—because they are better in material than ours? No; but because they have a beauty in design which leads the most illiterate to choose them. Why do we import such quantities of silks and carpets and chintzes and wall papers from France? The Cheneys make silks as good in quality on this side of the ocean as the Compagnie Lyonnaise make on the other; the Bigelows make carpets just as good in material here, as the D'Aubusson factory makes there, and yet when our wives and daughters see these foreign fabrics, they immediately prefer them. Why? Simply because there generally is in the foreign product a skill, a beauty, a taste in design that appeals to that sense of beauty which God has implanted in the rudest of our race.

Other nations in this warfare of industry see this. England is devoting millions to art education, in order to keep up her manufactures, and it has established in the Privy Council a science and art section to direct this expenditure wisely; Germany is doing even more; France has been doing it for generations, and it has given her the supremacy thus far in a multitude of branches of manufacture.

If you wish to see how these nations have done and are doing this, look at Mr. Stetson's admirable little book on "Technical Education." You will there see that Prussia alone gives industrial education in various branches to over 11,000 men.

Already the value of this is known to individuals among us. Mr. Stebbins tells us that one silver-ware establishment in the city of New York pays a graduate of one of these foreign schools for making designs and patterns, as high a salary as our Empire State gives its Governor.

MINING ENGINEERING.

Few among us dream of the monstrous waste now entailed upon this country by imperfect instruction in mining engineering and metallurgy. Take first the losses by fraud. A few years since our people were asked to invest in a Nevada mine of great richness. Half educated mining geologists had certified to its value. But certain capitalists sent a young man carefully educated in the Scientific School to examine and report. The young man on arriving found that the mine looked well enough, but on applying more scientific tests he found that an old worthless mine had been taken — that rich sulphurets had been brought and carefully placed in it at a cost of probably $100,000. His report exploded the fraud, and nearly $1,000,000 was saved —more than five times the sum that this scientific school received from the Government of the United States. This same gentleman also exploded a great diamond mine fraud of the same sort.

Take another case. Not long since a party of gentlemen determined to invest several hundred thousand dollars in working certain iron mines in this State. Just before their arrangements were finally made, and much against the will of many of the proposed stockholders, a young graduate of one of our scientific schools which received the national endowment, was sent to make an examination. He found that the veins contained titanium, and that the entire investment, should it be made, would be lost. His fee was $250; he prevented a loss of over $400,000.

You see now why Pennsylvania and Missouri, and California and Massachusetts, are aroused as to this matter also, but you will perhaps say that New York is little interested here. Look again at the census, and you will see how wretchedly you are mistaken. The value of the mining product of New York, in 1870, was more than half that of the entire gold product of California. Here, too, we must follow up the good work begun by our Chandlers and Raymonds.

CHEMISTRY APPLIED TO MANUFACTURES.

More and more the chemical laboratory is becoming a great central point in industrial education. Run over but two or three points out of many. A chemical discovery in coloring matter has given us a substitute for madder, and restored the great area given to cultivation of that material to the increase of material for human sustenance. An apparently trivial application of another chemical principle has enabled Onondaga to purify its product so that it now competes with the world in the purity of its salt for the dairy. Another application has enabled another part of the State to make quantities of steel formerly undreamed of. And all this is but the beginning of the applications of chemistry to increase the well-being of the State and Nation.

GENERAL INSTRUCTION.

And now a few words regarding the general education which goes with these various branches of industrial and scientific education. The old way in the more venerable colleges and universities was to force all students through one single classical course—the same for all. This system the "new education" discards. General courses in literature, science and arts, are presented as well as special courses having reference to the great industries, and the student with the advice of friends and instructors takes that which best suits the bent of his mind. We believe that the results are already better than those of the old system. Certainly they could not be worse. The famous Blue Book of the Parliamentary Commission on advanced education in England shows that under the old system there 70 per cent. of the students in their great schools and universities take no real hold upon classical studies. Few will claim that our system of classical instruction is better than that in England. We make no opposition to classical instruction. We agree that for those who take earnest hold of it, it is one of the noblest means of discipline and culture, but it is no less evident that for those who do not take hold of it—who merely "drone" over it—it is one of the worst.

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SCIENCE, INDUSTRY AND RELIGION.

And finally it is objected to the "New Education" that it is "godless." There is nothing new in this charge. It has been made against every great step in the progress of science or education. And yet it has certainly been found that although ideas of religion are changed from age to age, the change has tended constantly to make these religious ideas purer and nobler. The majority of the Fathers of the Church held the new idea of the rotundity of the earth incompatible with salvation. Martin Luther thought Copernicus a blasphemer for his new idea that the earth revolves about the sun, and not the sun about the earth. Dean Cockburn declared the new science of Geology a study invented by the devil, and unlawful for Christians. When John Reuchlin and his compeers urged the substitution of studies in the Classics for studies in the Mediæval scholastic philosophy, their books were burned and they themselves narrowly escaped the same fate.

No, my friends, every study which tends to improve the industry of mankind makes men nobler and better. Every study which gives man to know more of the history of his race, gives him to see more and more clearly the finger of Providence in history; every study which brings his mind into contact with the thoughts of inspired men as exhibited in our literatures, builds up his manliness and his godliness, and every study which brings him into close contact with nature in any of its fields not less surely lifts him "through nature up to nature's God."

I have thus sketched very meagrely the growth thus far of the "New Education." Its roots are firm, for they take fast hold upon the strongest material necessities of our land; its trunk is thrifty, for it is fed by the most vitalizing currents of thought which sweep through our time,—nay, the very blasts of opposition to this growth have but strengthened it. The winter of discontent through which it has passed has but toughened it; and in Agriculture and every branch of industry; in every science and art which ministers to either; in all the development of human thought which is to make men better and braver, it is to bear a rich fruitage for the State, for the Nation, and for Mankind.

PORTLAND CEMENT AND HOW TO USE IT.

From "The Architect."

Bad Portland cement is worse than useless, and is often the cause of serious failures, but it is just as unreasonable to abuse a good material, or in practice to treat it as if no reliance should be placed on it, as it would be to buy sand for sugar, and then to give up the use of sugar because the mixture bought was wanting in sweetening properties. The remedy is to see that you get the article you pay for; in order to do which, the first thing is to have a clear idea of the qualities which good Portland cement, suitable for all ordinary purposes, should possess. These may be described as follows:

CHARACTERISTICS OF GOOD PORTLAND CEMENT.

It should, when passed through a copper wire sieve of 2,500 meshes per sq. in., not leave more than 20 per cent. of grit behind. The cement sifted should not be less than 25 lbs., taken from different bags, or from different parts of the heap if stored in bulk. After a little experience a well-ground cement may readily be recognized by the absence of grit when rubbed between the fingers.

When made up without sand or excess of water, and filled up level with the top of a glass or similar vessel, it should set hard without cracking the vessel, rising or sinking or getting loose in it, or showing any signs of cracks in the cement itself.

When made up without sand, with as little water as possible, and filled into moulds, it should, after seven consecutive days in water, give an ultimate strength, under a tensile stress slowly applied, of 250 lbs. per sq. in. of fractured section, the immersion in water to commence as soon as the cement blocks will bear removing from the moulds, which should not exceed twenty-four hours after the moulds have been filled.

When time will not admit of this test being applied, a very fair idea of the strength of the cement can be arrived at from its weight, which should not be less than 108 lbs. per imperial striked bushel, filled up as lightly as possible, by pouring the cement down an inclined board, or through a wooden hopper, about 1 ft. sq. at top, 1 in. sq. at bottom, and 1 ft. deep. The hopper should be suspended with the point of discharge 6 in. above the top of the bushel measure, which should stand on a firm base and not on any vibrating floor, and should not be touched until the cement in it has been finally struck level with the top with a straight-edge. The cement weighed should be taken from different bags, or from different parts of the heap if stored in bulk.

When made up into cakes about ½ in. thick, without any sand or excess of water, the cement should set hard within 24 hours, either in or out of water, without showing any signs of cracks.

The color of good Portland cement is a bluish-grey; if dark and earthy, or of too light a color, it is not to be trusted. When made up without sand and set hard, it should show the same bluish-grey color without any brown specks or stains.

A high degree of fineness is necessary to the complete and simultaneous setting of all the particles throughout the mass. When insufficiently ground, the fine particles set first, then the coarser grit, and lastly the little hard lumps; and it is this process going on, after the surrounding particles have already set hard, which often shows itself all over the surface by the "blowing" or bursting out of numberless pustules, or the cracking of the entire body of the cement.

Some foreign cements allow of 85 per cent. passing through a No. 60 gauge, or 3,600 meshes per superficial inch; but cements of such extreme fineness are underburnt, and therefore weigh light, and are deficient in strength, though often rapid in setting. The wear and tear to the machinery in grinding well burnt cements to such extreme fineness would render them too costly to be marketable.

The test for expansion or contraction in setting is very simple, and one which should on no account be omitted, for these are about the most serious defects to which Portland cements are liable, though for the most part no steps are taken to guard against them.

Expansion in setting is due to the presence of free lime in the cement—owing either to more lime having been used in its manufacture than can chemically combine with the clay—to imperfect mixing of the lime with the clay, or to the burning not having been carried to a sufficient extent to enable the lime and clay to combine together.

Contraction in setting, which is not nearly so often met with, is due to an excess of clay, and, as there is no remedy for this evil, the cement must be rejected.

The tendency to expand in setting is a very common fault in fresh ground cements, especially those of the heaviest and strongest descriptions, owing to the large proportion of lime used in their manufacture, which, if in excess, as already explained—or even locally in excess, owing to imperfect mixing —is present in the cement in the form of free lime, which heats and expands considerably in the process of slaking. However, if the cement is otherwise good, this evil can be remedied by spreading it out on a dry floor, under cover, and turning it over occasionally, to allow of its air slaking or "cooling." Good cements are found to gain both in weight, bulk, and strength by being exposed to dry air for a few weeks, though the limit of such improvement has not yet been definitely ascertained. On this subject, Mr. Bernays, C. E., Superintending Engineer, Chatham Dockyard Extension Works—whose experience in the use of Portland cement is very extensive—in a lecture given at the School of Military Engineering, Chatham, says:—

"When delivered on the works for use, Portland cement should always be shot from the bags on to a wooden floor—to a depth not exceeding 4 ft.—and be permitted to remain at least three weeks before it is allowed to be used for any purpose. While so kept, fresh Portland cement increases considerably in bulk—probably 10 per cent. —without any diminution of its strength; so that it should be to the advantage of a contractor to store his cement before using it, even if he were not required to do so by the engineer. I can hardly impress too strongly upon you the importance of avoiding the use of fresh cement for any purpose whatever."

Many a good strong cement which, when first delivered, would heat in mixing and expand in setting, would, after exposure to the air for a time, stand the test for expansion perfectly; but after such exposure, the other tests should be carefully applied, in order to insure its not having deteriorated in strength and rapidity of setting. A further advantage gained by spreading the cement out on a floor, where large quantities are being used, is that it tends to mix up the contents of the different bags or casks, and so to produce a greater uniformity of quality throughout.

The cement for the test blocks must be carefully made up without excess of water, and the moulds well and soundly filled in, or its full strength will not be developed. If, in the absence of a proper testing machine, the strength test is applied by suspending weights in a scale, or otherwise, slung from the lower end of the cement blocks, the gradual increase of the stress should—after about 150 lbs. per sq. in. has been applied—be insured by pouring water or shot into a vessel suspended from the block, or by placing a chain, link by link, in the scale or in a pail suspended from the specimen. It is not wise to aim at obtaining very heavy cements capable of attaining extraordinary strength, and therefore it is that the strength test, as given, is put at 250 lbs. per sq. in. of fractured action, instead of at 300 or 350 lbs., as is very commonly insisted on in modern specifications. Great weight and strength mean high burning and slow setting, the former resulting, as already explained, in coarse grinding, with all the attendant risks of blowing and cracking, and the latter in deferred strength; but it should be remembered that in practice the cement will, as a rule, be called upon within a few weeks, or months at the most, to do as much work as it will ever have to do, and therefore, that if strong enough then, it will be strong enough always; consequently, that any extra strength acquired a year or two later will be of no practical utility.

In judging of the strength of cements from their weights, the fineness test must never be omitted, since weight may in a great measure be due to coarseness. If great strength is required it will always be safer to use a moderately heavy cement with less sand or other material mixed with it, than run the risks attendant upon the use of the heavier cements, with a larger proportion of sand.

For common purposes, such as pointing, when cement of a very high quality is not necessary, and no tests are ordinarily made, it is always advisable to mix one or two parts of sand with it, and not to allow it to be used neat, in order to guard against its shrinking in setting, which, in the case of pointing, would make it loose in the joints, and lead to the wet and frost getting in, and to its soon requiring renewal.

Very rapid setting and great strength are not met with in the same cement; but in many cases the quicker setting and lighter cements are most useful. It is believed that before long light Portland cements will be manufactured, capable of competing with the Roman cements in quickness of setting, and surpassing them in quality.

The following table contains the result of a series of experiments made by Mr. J. Grant, C. E., whilst engaged on the Metropolitan Drainage Works, with Portland cement, weighing 123 lbs. per bushel:—

Average Breaking Test of Ten Specimens.

Age.	Neat Cement.	1 Cement, 1 Sand.
	lbs.	lbs.
7 days......	817.1	353.2
1 month....	935.8	452.5
3 "	1055 9	547.5
6 "	1176.6	640.3
9 "	1219.5	692.4
12 "	1229 7	716.6
2 years.....	1324 9	790.3
3 "	1314.4	784.7
4 "	1312.6	818.1
5 "	1306.8	821.0
6 "	1308.0	819.5
7 "	1327.3	803.6

The whole of the specimens were kept in water from the time of their being made up to the time of testing, and the breaking weight applies to a sectional area of 1½ in. sq., or 2.25 in. super. It appears from these experiments that neat cement of 123 lbs. per bushel took two years to attain its full strength, whilst the admixture of sand, in addition to weakening the specimens, also delayed their attaining their maximum powers of resistance.

A dull earthy color denotes an excess of clay; whilst too light a color is the result of either under-burning or an excess of lime, or of both these faults combined.

Since Portland, unlike Roman cement, improves within certain limits by exposure to the air, it need not be packed in air-tight casks (except for exportation), but, so long as it is kept dry, may be kept in ordinary casks or bags as may be most convenient. The casks in which it is packed generally contain four cwt., and the bags two cwt.

Salt water does no injury to the strength of the cement, but must be avoided where efflorescence or damp on the surface would be objectionable.

Both cement, mortar, and concrete should be made with as little water as will suffice to make the whole cling together. When too much is used, the finer particles of the cement get separated from the rest and float away, or on the surface, in the form of a slime. In mixing concrete, if the ballast is porous and dry, more water will be required than if damp or non-absorbent.

Experience has shown that porous materials, by allowing the cement to enter the pores and so retain a firm hold on them, are the best for mixing with cement; thus, well-burnt broken bricks, clay ballast, furnace slag or breeze, will form a stronger concrete than if made with the harder but smoother and less porous stones in gravel or shingle; but it must be borne in mind that in such cases a slightly larger proportion of cement is advisable to compensate for what is absorbed by the pores of the material.

No importance need be attached to the shape of the particles of sand or other materials used—such as whether angular or water-worn—though a certain roughness of surface gives a better hold to the cement than if too smooth. The presence of dirt, such as loam, clay, and vegetable matter, liable to decay, has a prejudicial effect upon cement, and sensibly weakens either mortar or concrete.

The gravel, broken stone, or other material used in making concrete, should have sufficient small stuff and sand mixed with it to fill up the interstices between the larger pieces. When this is not already the case, the amount of small stuff and sand which ought to be added may be ascertained by filling up any suitable measure, of uniform section from top to bottom, with the gravel, etc., striking it level with the top, and then adding as much water as the measure will contain. The water may then be run off through a hole in the bottom of the measure, the gravel, etc., removed from it, and the water replaced in it; the amount of water, expressed in terms of the internal height of the measure, will be the proportion of small stuff which should be added to the ballast.

As cement is not used, on account of the cost, unless special strength is required, the proportions in general use are 1 cement to either 1 or 2 sand; below this the advantage gained by its use diminishes rapidly. In general terms, neat cement is $\frac{1}{3}$ stronger than if mixed with 1 sand, and twice as strong as when mixed with 2 sand.

For concrete, 1 cement to 10 or even 12 gravel, or other material, is sufficient for masses in foundations, dock walls, etc.; 1 to 8 or 6, for ordinary walls, according to their thickness; and 1 to 4 for floors, and other places where great transverse strength is necessary.

The best method of mixing concrete in large quantities is, taking a measure of convenient capacity for one mixing, to half fill the measure with the broken ballast, or other material, and then add the cement; finally filling up the measure with the ballast. The measure should then be lifted off, when the whole will fall into a heap, the cement partially mixing with the ballast in so doing, and not being so liable to get wasted by being blown about by the wind, as when emptied over the top of the ballast heap. The whole should be turned over twice dry, and then shovelled to a third heap, sufficient water only being added in so doing—by sprinkling from the rose of a watering pot—to make the ingredients cling together in a pasty mass. The floor on which it is mixed should be hard and clean.

The concrete may either be wheeled off and deposited in position, or, if more convenient, may be thrown down; but in both cases, more especially in the former, it is advisable to beat it down lightly with wooden beaters until the moisture comes to the surface.

On no account should it be sent down a shoot, or the finer and coarser ingredients will get separated in the descent, the former clinging more to the sides of the shoot, whilst the latter will reach the bottom first, and get shot out into a heap by themselves.

When cement work has once been laid, it must not be touched until quite hard, for its strength will be materially affected if the particles are disturbed after the process of setting has commenced.

All absorbent surfaces or materials, with which cement is to come in contact, should be well wetted, or they will rob the cement of the moisture necessary to enable it to set hard; but the water should not be oosing out of them, or the cement, being unable to enter their pores, will fail to adhere properly to them. For this reason broken brick ballast, etc., if quite dry, will require more water in concrete making, than if already damp, and old dry walls will require more wetting than new or external damp walls.

Cement work must be kept damp until set quite hard, or it will become rotten from the evaporation of the water of mixing, which is essential to the proper setting of the cement; hence the most suitable time for executing cement work is in damp weather. When the work has to be done in dry weather, special care is necessary to keep it damp, and to protect it from the sun's rays. Flat surfaces, such as floors, paving, etc., should, if practicable, be kept flooded with water or covered with a layer of sawdust or sand 3 or 4 in. thick, which should be kept quite damp for at least seven days, or until the cement has become quite hard. In surfaces exposed to traffic, this is most important, as the cement, if at all perished, will soon wear away.

Cement mixed with sand and other materials is porous, admitting both moisture and air; iron, therefore, imbedded in cement work, is liable to rust, and the expansive force accompanying this process, will split up cement, stone, or any similar unyielding material.

MACHINERY AS APPLIED TO THE MANUFACTURE OF WATCHES.

By T. PERKINS.

From "The Engineer."

That our American cousins have gone far ahead of us in the application of labor-saving machinery is a truism which has become almost stale by repetition, and is capable of proof by reference to their very complete "Patent Office Reports," or to the pages of their scientific and technical journals. Scarcely can we find a department of trade in which some automatic machine does not supply the place of dear skilled labor. But in no branch of manufacture has automatic machinery proved such a thorough success as in the production of watches. In the manufacture of small arms, the application of machinery to the making of interchangeable locks and stocks revolutionized the trade, and to this manufacture are the Americans indebted for a system which has supplied them with a home-made watch; for a system which is ultimately to become the leading one alike in England, France, and Switzerland. It is useless for English watch manufacturers to say "the thing can not be done, the machine-made watch can not beat the hand-made English lever in the home market." To their own cost, the record of the past proves the fallacy of such argument. Twenty years ago, America was supplied with her better class of lever watches almost wholly by Coventry and Liverpool, the demand for a common article being met by a large importation of movements of Swiss and French make. To-day, these latter countries supply, still, the enormous demand of the States for cheap work, but more than 90 per cent. of the good lever watches are now of American make. The machine-made watch has supplanted not only the product of the skilled French operative, but that of his more highly skilled English brother.

The reasons which have led to this result are diverse. National pride *may* have had something to do with this, but the protective tariff, so often put forward by the watch trade as the leading reason, has had positively nothing to do with the defeat of the hand-workers, who gave up the contest ingloriously. The truth is that the American watch companies have never yet known anything of trade competition, have never yet been able to keep pace with the demand for their products, and the main portion of their success must be attributed to their machinery—to the fact which is becoming more and more evident daily, that machines planned by brains at once scientific and practical must beat the simply practical rule-of-thumb workman, and that arms and muscles of iron will outwork and outlast mere flesh and bone. At the present moment, the watchmakers of England are unable to supply the home demand for their products, and it may therefore be *apropos* to draw attention, for a few minutes, to the machine-system as applied in the United States. As is generally known, the English system divides the manufacture into a vast number of branches, in each of which the work is performed by hand, or by the use of very simple lathes, driven by manual or foot power. In only three instances in England, are we aware of the employment of steam power in the production of watches, and in one instance only, is duplicating machinery used, and then only in the production of the plates or the rough movements. The American system subdivides the manufacture into a much larger number of details, and apportions a machine to the perfection of almost each operation, leaving not more than 10 per cent. of work to the skilled workmen.

It will be, perhaps, best for us to indicate, in a few of the departments, the advantages and saving effected by the machinery employed. First, in the manufacture of the movement. In the preparation of the plate a principle is laid down in the first punching performed on the circular sheet of brass. We want our movements interchangeable. To do this we must make our holes of all kinds, in exactly the same position in each watch; we must always, in determining a position in the watch, have some relative position from which to revolve it. The three dial feet holes immediately suggested themselves as affording a means to the desired end, and the punch was therefore brought into requisition to place these holes at certain angular distances from each other in all plates of any series. Here, then, we find machinery supplying the means of at once determining the position of each pivot hole in the watch, it being necessary only to prepare a chuck, on the face of which are three studs so placed that when the plate is laid on its face with the studs in the dial feet holes, the drill finding the centre of revolution shall correctly make the hole required. And it is very easy at once to see how this principle may be applied to the determination of every hole in the watch. No templet plates and drill guides are here needed, with their uncertainty and subsequent filing and fitting; no running of each depth, with marking and cross-marking, dotting and hand-drilling, topping or stretching to make or correct depths. But the position once laid down is certain in each plate until the chuck is worn out.

The American spring-chuck lathe is too well known to need description, and yet it forms a ready means of securing a reproduction of any required height or thickness of turning. In the ordinary form the merely casual observer will see that if the rear bolt which draws the chuck down to the bevel be tightened a little more or less, the piece held will be thrown a little further from or nearer to any fixed tool or cutter, and therefore no advantage could be gained over the old cut-and-try system. This is overcome, however, by making the chuck face a fixed position, and by closing it on the piece to be held by advancing the spindle bevel from the rear. It will be seen at once what is gained. The piece to be shaped and the operating tool are always in relative positions that can be relied on, but little judgment is required of the workman, who has only to keep the tool in order, to insert the work in the lathe, and, in some instances, to feed up the cutter to its work. But in the manufacture of the wheels and pinions still less is left to the judgment of the operative, for the larger portion of the cutting and shaping machinery is automatic. In England the custom is to revolve the work to be turned on dead centres in a hand lathe with drill bow and screw ferrule, and with a graver to cut away metal upon each down stroke of the bow, freeing the point of the tool during each upstroke. Such work can only be done surely after long experience, and with the exercise of great care to secure perfect truth. In America we see all turning of staffs, arbors, and pivots done by a sliding or engine lathe. Not such an one, of course, as is to be found in our engine works, or gun shops even; but a tool made to take a cut varying in length from one-twentieth to one half of an inch, and calculated to reduce diameters down to one two hundred and fiftieth of an inch. Such a machine, with an industrious girl to feed it, will make two thousand cuts per day.

The tools for the production of the teeth exhibit a marvellous advance upon those in use either in England or Switzerland. As is well known to all practical machinists, the controversy is an old and long one with respect to the form to be given to the teeth in geared work. English and Swiss horologists incline to the use of the involute curve, or to a compromise, while the Americans adopt wholly that of the epicycloid. But although the wheel cutter of the older countries may defend warmly the use of either curve, the nearest he can come to producing it in his work is to lay it off very large, and transferring it to a templet to serve as a guide to his eye, with graver and file, then to form his cutters so that they shall produce a curve that looks something like the one projected mathematically. Not so the American. He makes a machine in which he obtains the proper curve at once on his cutter laps, using the generating circles themselves as the initial point in the process. So he does away at once with the element of doubt, and instead of saying, "I think the teeth or leaves are such a curve," he can say, "The curves beyond the pitch lines are epicycloidal, obtained from their own generators." So also by his arrangement of machinery he can be sure that the division of teeth and spaces is the best which experience has taught, and that the radial undercut is nicely proportioned. But the machines in which the wheels and pinions are cut evince also a great advance over the modes in use among our old school workmen.

The old English or Swiss cutting engine with its universal index plate was an ingenious contrivance, and served its purpose, and may be useful for many years to come in the country jobbing shop, but it cannot hold its own in the Lancashire movement shops much longer. The power of indefinite and rapid reproduction is one which will be required, and which the tools spoken of are incapable of. The American wheel cutter is a tool which combines ease of handling with certainty of reproduction. By its use a girl can cut more wheels in one day than a skilled English workman can cut in three days, and can cut them better.

The machine spoken of is only an adaptation of the milling tool. It is very simple in its construction, care of course being taken to obtain close adjustments. It consists of a revolving spindle attached to a traversing bed, which can be worked by a rack and pinion attachment in connection with a lever arm. The blank wheels are placed on a "quill" at right angles to the revolving spindle, and at the base of the quill is secured a spaced disc or index plate having the same number of spaces as there are to be teeth to the wheel. The revolving spindle is pierced in a right line with the centre of the quill, to receive a cutter shaped to fit the space between two wheel teeth. The tooth cutting is effected by securing a stack of wheel blanks to the quill, revolving the cutter spindle very rapidly and traversing it so as to cut a groove through the entire stack. Raised again the stack is advanced one notch by means of the index at the base of the quill; another groove is made, and the operation is repeated until the whole circumference is fitted, when we find that we have made twenty-five perfect wheels in little more time than the Swiss could have made one. The fine adjustments of the machine render it capable of cutting teeth for a coarse train timepiece, or for the delicate high numbered train of a four or six-sized lady's watch. The English still use drawn wire for their pinions. One Lancashire gentleman has, we believe, lately attempted to cut them from the solid wire, but has met with such a storm of opposition from his workmen that he has desisted. The American pinion cutter is only an adaptation of the wheel cutter, using three small circular-shaped saws instead of one cutter, and operating one pinion at a time.

The tools used for finishing and polishing the pinions are simply an adaptation by machinery of the motions of the hand-worker, and by cam, eccentric, or connecting-rod, we get all the beautiful polish which can only be produced by a perfect crossing of the lines of abrasion. Here also the grinding machine is used to reduce to absolute truth the hardened and tempered staffs of balance, pallets, and escape pinion.

In the manufacture of the escapement again there is to be found nothing of the uncertainty of the English workman; he knows nothing of the scientific reasons for making certain angles to his pallet stones, and could not prove to you mathematically that they were any certain angles. He has simply a set of gauges which have been handed down to him by the tradition of the elders, errors and all, and he grinds and files everything to these gauges. Not so with the machine-made escapement. The escapement laid off scientifically, the wheel will be found always the same, although cut in a very similar machine to the tooth-cutter already described, the only difference, indeed, being that it has several shaping tools instead of one only. The pallet angles must be correct, for the machinist made a tool by which only the two inclinations of the planes can be obtained. The pallet slots are assured in the same manner, for the little milling machine can only traverse in the right direction. So with the roller; turned to an exact size, the drill makes the ruby pinhole in a position which is constant in all of that size, and the grinding lap cuts the crescent to the same depth in each roller. The ruby pins, too, by an adaptation of the grinding machine, are produced of an uniform diameter.

The only other thing noticeable in this branch are the gang skives, which are similar in their arrangement to ordinary gang-saws, the difference being that they effect by diamond powder upon nodules of precious stone what the teeth of the saws effect in wood, namely, a severance into planks and posts.

The machinery used in the manufacture of screws is simple. The spring chuck lathe is used to hold the steel to be operated on. A Swiss slide rest carries the shaping cutters, and the thread is cut by an ordinary jam die. These dies and the standard taps are cut in a little gem of a lathe, which is only a miniature of the screw-cutting engine to be found in any ordinary machine-shop, and is capable of cutting up to 200 threads to the inch. The old slotting file, too, is not found here, the slits in the screw-heads being made by a circular saw which traverses a row of about a hundred at a time, thus effecting perfectly in the large number the work which the hand-worker takes a longer time to do imperfectly on one. The manufacture of flat steelwork calls for much the same kind of machinery as we found in the train room, adapted, of course, to the peculiar shapes it is to produce, the specialties of the department being found in the tools used to grind and finish the curved surfaces.

Compensation balances call for but little special machinery, the most noticeable being the index chuck, in which are drilled the holes for the adjusting screws, an arrangement which enables the operative to drill the twenty-two holes without removing the work from the lathe, and to finish in this manner 100 balances per day.

By the aid of self-measuring tools the jewelling of the watch movement is reduced from the specialty of a skilled workman to a job which may be picked up by any ordinary *employé*. It is painful to see the unnecessary labor expended under the English method in cutting and trying till the perfect fit is obtained.

The swing rest does away with all necessity for this, as it causes the cutter itself to determine the correct limits of its work. A fixed vertical arm is attached to a tail stock-bed, having at right angles to the top a nose on which may be placed the jewel or other article to be measured. Swung on a hinged joint also to the tail stock-bed is a spindle-cutter rest, pierced in a line with the lathe centre for the reception of the spindle, and carried the same distance beyond the lathe centre as that point is above the hinged joint. This extension is so made as to slide close over the fixed nose spoken of before, and the whole is so arranged that when the cutter-rest is swung close to a stop on the nose the centre line of the cutter is coincident with that of the lathe head. The action of the tool is obvious. If a jewel be placed on the nose and the rest be brought up close to it, that portion of the tool will be subtended a radial distance equal to the diameter of the jewel, and at the cutter line it will measure the radius of the jewel, and so will cut the hole the exact size required. This machine is found of infinite service in fitting up the watch, as it does away in many cases with the necessity for broaching holes to fit, and a traversing index-bed will permit, should occasion demand, a hole to be cut of any degree of taper. The pump centre lathes differ but little in principle from those to be found in the workshops of the Old World. But the jewel-opening lathes are very greatly superior to the Clerkenwell tools. They consist of a spring-chuck head-stock to hold the jewel and a revolving spindle for the copper opener. The arrangement of this machine insures a perfectly round hole, a result never certainly attainable under the hand method, and it also permits the employment of unskilled labor in what has hitherto been a most delicate operation. It is found expedient in the finer grades of work to give to each watch an individuality, and to make absolutely correct the distance between the jewel faces of the 'scapment work. To effect this an attachment is added to the swing-rest which enables the operative to make the plates and staffs self-measuring, and so to cut the shoulder on the jewel setting just the height necessary to give the staff .0006 of an inch and shake.

In the remaining branches of manufacture —those of dial making, gilding, and setting up—the processes are only such modifications as would suggest themseves to any large manufacturer, and consist chiefly of a minute division of operations. But not only do we find an advantage in respect of the watch-making tools proper, we find also very great superiority in the appliancess for making these tools. The use of labor-saving contrivances in America in all the avenues of trade has given rise to especial machinery for their production, and this is very noticeable in the watch factory machine-shop. The screwing and sliding lathes are made to meet more varied requirements than are the English articles. Planers, too, are capable of adjustments which are not attainable, except in very expensive machines, in England; and in small form, with a 4 in. or 6 in. stroke, we have as yet failed to find the machine. Another most useful tool, which is an absolute necessity to the watch machine shop, is the universal milling tool; and indeed no machinist can afford to be without it if he has once used it. Yet we can find in England no tool which can take its place, or which combines such a multiplicity of operations. It is adaptable not only for all ordinary milling, but it can be used to cut straight or spiral reamers, drills, and mills. It can be arranged to cut spur or bevelled gears and it can also be used to cut straight or spiral cones. The movement and feed of the tool-carriage is automatic, and it is provided with adjustments for any desired angle. Such a machine cannot but be a favorite with close workmen on fine work. A machine wholly unknown outside the watch factory is the parallel and cone grinder, a modification of course of the grinding tools now replacing the file in so many shops. This machine reduces to absolute truth and fit the hardened steel spindles and bearings which are the specialty of watch-making machines. By it any taper given to the spindle may be reproduced in the bearing, sleeve, or collar, and the fit is at once removed from the region of doubt. Any desired degree of finish, too, may be attained, that usually preferred being by the use of diamond laps. So it will be seen that while the tools for the manufacture of watch-machinery are very fine, there is no lack of means for the production of highly-finished and perfect work.

The picture of this American machinery teems with lessons to the Englishman. To the machine-manufacturer it speaks very loudly. We must all bear witness to the marvellous beauty and finish of some of our English lathes, with their ingenious compound rests for the turning, etc., of shaped surfaces. But nowhere in England can we see such lathes as we find mounted on the benches of the watch factory; nowhere on this side of the Atlantic can we see tools so well made and closely fitted or provided with such multiplicity of adjustments for the close correction of errors resulting from wear or otherwise. This state of things is due alike to the lathes and men of the machine-shop, for the system has most certainly produced a set of workmen who are second to none as practical machinists, and, in all probability, cannot be equalled.

To the watch manufacturer it speaks very loudly, especially so in the present state of the trade, when a gentleman, who turns out 160 watches per week cannot increase his supply, cannot meet half the demand upon him, simply because he cannot get workmen, and apprentices take so long learning. Machinery, once made, is always ready, and is as good for twenty hours a day as ten. To the capitalist it speaks very loudly, in the face of an increasing demand, of which over 60 per cent. is met by the importation of an inferior French or Swiss article; and the capitalist must recollect, too, that the machinery is not an experiment, but an assured success, which is now paying 40 per cent. on the investment of capital, and that its use at once doubles the productive power of the operatives, for Clerkenwell takes over seventy hours to make a watch, while Waltham produces one for each thirty hours of labor.

To the intelligent public it speaks, offering reliable work at a cheap rate, and, in repairs, placing them beyond the reach of irresponsible and ignorant workmen, and making the duration of a valued watch not such a matter of uncertainty as at present. So we may ask the question, in all sincerity, which has often been made to us, Why does not England adopt the watch-making machinery of America?

SCIENTIFIC ERRORS.

From "The Architect."

Professor Tyndall recently demonstrated before a brilliant audience, that certain ideas which have been held for the last century and a half by all natural philosophers as to the power of the atmosphere to transmit sound are altogether erroneous. For more than a hundred and fifty years a statement has been repeated by one scientific writer after another, to the effect that the power of the atmosphere to transmit sound corresponded with its power to transmit light, or in other words, that the clearer the day the further could sound be heard, and the denser the mist, fog, or rain, the worse for the transmission of sound. This dictum, for which what passes as high authority could be adduced, proved entirely misleading when put to the test; so much so, indeed, that it would be hard to see how it can have escaped formal contradiction all these years, did we not know how very ready we all are to take for granted anything which a man with a name that carries weight says in an authoritative way. Sounds of great space-penetrating power, including the reports of an 18-pounder gun, which, on some occasions, were heard more than 12 miles out to sea, proved during the Professor's experiments, inaudible on many clear days at distances varying from 5 miles to 2, the weather being on those days fine and sunshiny. The true nature of the impediment which thus shortened the range of hearing was traced out, and proved to be the presence in the atmosphere of innumerable strata of heated air and invisible vapor ascending from the surface of the sea, heated as it was by the rays of the sun, falling with powerful effect upon it. With this explanation, however, we have not much to do at the present moment, though it is not impossible that some important light might be thrown by the learned Professor's remarkable experiments upon the condition of the air within a public building, and its power to transmit sound. We simply refer to the circumstance as a notable example of the necessity for bringing all scientific statements to the test, and repeating the experiments till there can be no doubt that the facts, which they are supposed to establish, really exist. And we further ask—if this misconception can have gone on so long unchallenged, and almost unsuspected, may there not be ideas, at least as erroneous, which pass current respecting the science of building? Have we no theories of construction with respect to which, a short but searching investigation would prove the mistake to be, at least, as great as that which it has recently fallen to Professor Tyndall's lot to correct?

We believe ourselves to be well furnished with data from which to compute the strength of timber, stone, brick, iron, cement, and all the materials upon the use of which depends the stability of our buildings; but it is not going too far to assert that, except, perhaps, in the case of iron, no experimental data, worth dignifying with that name, exist, and it is doubtful whether such trustworthy information as has been obtained as to some of the properties of iron, has been applicable to any extent to its use for the builder's purposes. We know, indeed, a great deal about Destruction. The range, the initial velocity, the penetrating powers, and the crushing effect of missiles of all classes hurled from every description of gun by the force of every possible explosive, have been tested accurately, and the strength and quality of the armor plating sufficient to withstand each description of butt attack, have been determined with precision; how about the arts of Peace? We know pretty well what iron will do in the way of destroying life; but most of the work in which that material is used to protect life is done in a rule of thumb kind of way, and proceeds upon no exact application of the results of the scientific investigations which have taken place; while as to those very investigations, when we come to ask whether they were searching, exact, repeated till the possibility of serious error had almost disappeared, and tried on such a scale and with such apparatus as would insure accuracy, we find much to disturb our confidence.

The testing machine employed by Mr. Anderson, whose popular work on the strength of materials is perhaps the best, as it is certainly the most readable of all works on such subjects, is described by him, and proves to be one of very convenient application to small specimens, but it is not capable of taking in large ones, and it is only equal to exerting a force of 25 tons as a maximum. Probably the work done in this machine is fairly registered, but if we turn to experiments where a greater power has been wanted, we find that in all of them hydraulic rams have been employed, in the use of which the force is estimated by a pressure gauge; but "however carefully"—these are Mr. Anderson's own words—"pressure gauges may be constructed, they are liable to alteration and error. In addition, when the load has to be calculated from the pressure in the press cylinder, the friction of the ram must be allowed for, and this cannot be done with any great accuracy."

The condition of matters is in short this. We possess formulæ for the strength of timber, calculated upon the behavior of specimens not much larger than sticks of firewood, and formulæ for the strength of stone, calculated upon the basis of bits fit for use as paper weights or cabinet specimens. We have tried experiments, but we are quite unable to say how far the known inaccuracy of the usual testing machine has interfered with our results; and we have trusted to a few trials, and those with small pieces of material, without being able to say how far the analogy holds between the strength of a stick whose bearing is measured in inches and that of a beam whose bearing is measured in feet.

There is some reason for supposing that small specimens of stone may give a result not very disproportionate to that given by large blocks; but we know of no published results to prove it. There is, on the other hand, strong reason for believing that the strength of timber in the log is not at all in proportion to that of timber cut into small specimens, but this surmise has to be gathered rather from the experience of failures in the use of timber, than from any scientific inquiry. We may find it prudent to give a large excess of strength wherever we can, for the sake of securing stiffness and avoiding risk; but there are occasions where every constructor has to reduce some part of his construction to what he believes to be near its minimum safe strength; and on such occasions the painstaking architect or engineer is often oppressed with a vague sense of apprehension, if he attempts to satisfy himself as to the solid basis upon which has been built up the plausible and complete series of formulæ offered for his acceptance in the usual books of tables.

It is with a view to show the way out of these uncertainties that the Committee for arranging that part of the London International Exhibition of 1874, which relates to building materials and appliances, have unanimously decided that it is most desirable to conduct a series of experiments upon building materials on a scale, and with an accuracy, sufficient to insure trustworthy and useful results. They do not of course propose to settle all questions of construction, or perhaps even to dispose of any; but they propose a specimen series of experiments, such as should show what can be done with materials in common use, and of dimensions such as constantly occur in buildings. They propose to exhibit the materials after they have been broken in the testing machine; and to publish an accurate record of the weight under which they failed, and of their behavior during the previous stages of the experiment short of their failure.

For this purpose the magnificent testing-machine of Mr. Kirkaldy, is now available. The principle applied in that machine is that described by Mr. Anderson, the authority already quoted, when he says:—"The best kind of hydraulic machines are so contrived that the precise force which is exerted by the water is shown by a delicately-adjusted steel yard." Specimens of great length and large scantling can be taken into this machine. The powerful force available is equal to the destruction of these specimens, and the construction of the registering arrangement is such as to indicate with perfect accuracy the force exerted at any moment, and the deflections it occasions. The Committee have accordingly recommended the use of this machine in the proposed experiments, and have drawn up a list of what experiments they would like to try should the funds be obtainable. They wish to expend £500, and they hope that the Royal Institute of British Architects, the Institution of Civil Engineers, and the Society of Arts might be induced to vote money towards the expense. It is to be presumed that the Committee have been encouraged to understand that Her Majesty's Commissioners would also contribute liberally towards an undertaking which, if well carried out, will go far to render their exhibition interesting to every person connected with architecture, engineering or building.

We have before us, as we write, a list of all the suggested experiments. It is printed for private circulation only, and we do not feel at liberty therefore to transfer it to our columns; but we may venture without indiscretion to give such a general idea of its nature as to say that it includes the behavior of large beams of various woods under breaking and under thrusting strains; the behavior of rolled iron joints, flitch girders, stone steps, and stone landings under breaking strains; the behavior of stone columns and cubes of stone (from various quarries and variously bedded) under thrusting strain; the resistance of piers of brickwork, and of bricks of many different kinds, to a similar strain; and the resistance of cement to a tensile strain. It is proposed to try not fewer than three similar specimens of each sort, and the total number of single experiments appears as if it would considerably exceed two hundred.

We can only say that this proposal has our cordial approval, and that we sincerely hope the necessary funds will be forthcoming. It will of course best conduce to a valuable result if the materials to be tested, or the bulk of them, are such as are procurable by builders in the way of trade, and purchased in the open market, not selected specimens such as would be submitted for exhibition. This has probably been contemplated in the estimate. At any rate it ought to form part of the scheme, for if no timber but the very strongest, no stone but the very choicest, and no iron but the very finest be tried, we shall still be as far as ever from knowing what strength we may fairly expect to find, if, in an ordinary building carried out in the usual manner by a builder who has gained it in competition, we employ a beam or a column of the same scantling as in the Committee's experiments.

It would be well worth while if the Institute would encourage experiments by keeping a record of tests undertaken by its members, and publishing the same from time to time. It would be especially valuable if a good series of failures could form part of this record, and though there is often difficulty in obtaining the accounts of such disasters as are not accompanied by loss of life, still they are to be had, and they are eminently instructive. For example, the two most ambitious timber roofs erected in London within the last five-and-twenty years have both failed. We allude to the collar-beam roof at the South-Eastern Station, London Bridge, and the laminated rib roof at the Great Northern Terminus, King's Cross. There ought to be no great difficulty in obtaining exact accounts of how they failed, and why? There is no secret about their having been unsuccessful, and in each case the reputation of a living architect would not be affected. These, therefore, would be good examples of failure, and such as might fairly be published. Examples of tests are not of frequent occurrence, but even now they are carried on from time to time; they deserve every possible encouragement, and no more useful course could possibly be taken than to put them on record. It is, therefore, with great pleasure that we have seen this proposal on the part of the Exhibition Committee, and we feel sure that, if carried out, the experiments, and the published record of them, will be equally valuable as examples, and acceptable on their own merits.

FOUNDATIONS UNDER WATER.*

By GABRIEL JORDAN, C. E.

Within the last three years, the writer has had occasion to construct a bridge for the Mobile and Montgomery Railroad Company, across Tensas river, in the State of Alabama. The substructure consisted of 12 piers of 2 cylinders each, and a draw-pier of 8 cylinders; the superstructure was composed of 12 spans of 152 ft. each, and a draw-span of 260 ft., on the plan of a triangular truss (Fink's improvement).

Tensas river is the largest of the many outlets or bayous of the Mobile river; it is 2,100 ft. wide, and from 16 to 35 ft. deep, with a daily tidal action of only about 16 in. The bottom of the river to a very great depth is formed of a light shifting sand, subject to deep and troublesome scouring with the slightest contraction or disturbance of the water-way.

The means of the railroad company were too limited to admit of the pneumatic process, and other plans practised in this country presented the double objection of expense and tendency to produce serious scour. After carefully investigating all the conditions incident to the work, it was determined to use wooden pile piers incased in cast-iron cylinders.

The piles were driven in two clusters of 12 piles each, the cylinders were then lowered over them and filled with concrete—the whole work presenting very much the appearance of the ordinary pneumatic piers built in many parts of our country. The piles were driven to a depth of 30 ft. into the sand, with an ordinary floating steam machine. The first pile in each cluster always drove with ease, and would yield from 2 to 3 in. under the last blow of the hammer; but as the number of piles increased, the resistance increased in a rapid ratio, until no appreciable effect could be produced on the last pile of each cluster, after reaching the required depth. After the driving of each cluster was complete, the piles were thoroughly bolted together with $1\frac{1}{4}$-in. bolts, and all sawed off near the surface of low-water.

The cylinders (6 ft. in diameter, $1\frac{1}{4}$ in. thick, in sections of 10 ft., connected by inside flanges and bolts) were lowered into position over the piles to the sand bottom. The work of handling the cylinders was all done from a floating derrick, with heavy blocks and lines and the portable engine used in driving the piles.

Attached to the derrick boat was a small rotary pump, taking its water through a 4-in. suction pipe immediately from the river, and run at a speed of from 200 to 300 revolutions by the same engine used for the other work. The discharge pipe was made of very heavy canvas hose, 3 in. in diameter, about 50 ft. long; it led to a cast-iron cone about 10 in. in diameter, from which radiated 12 gas-pipes, 1 in. in diameter and about $2\frac{1}{2}$ ft. long. At the end of each of the 12 short pipes was attached a right-angled elbow, and to each was connected a pipe leading down into the cylinder to be sunk. These pipes were made in sections about 10 ft. long, so as to lengthen them to any extent, according to the depth of work required. This little appa

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* Transactions of the American Society of Civil Engineers.

ratus was lowered and raised at will, with a light block and line. As soon as the pipes were lowered into position on the sand, and the pump put in motion, they would sink with great rapidity, very often falling as much as 10 and 15 ft. at a single impulse. The sand would at once be put in an active state of ebullition, thus destroying the friction, and the great cylinders would quietly and sometimes quickly sink to the required depth of 15 ft. below the bed of the river. The movement of the cylinders was not uniform, but varied with the nature and density of the material passed through; it often required several hours to sink one a single foot. In sinking a cylinder of 4 ft. diameter, in the draw-pier, under the immediate supervision of the writer, it was carried to a depth of 14 ft. in about two hours; the remaining foot was overcome only after 5 or 6 hours' hard pumping and labor. The resistance came from a small deposit of clay, which was finally removed or scoured away by using a single pipe and jet of water on the outside of the cylinder.

While sinking one of the large cylinders, the engineer in charge telegraphed to the general office, that he had encountered a car-wheel about 2 ft. under the sand, which had been used as an anchor for a buoy, and that he had no appliances for removing it. While a plan for relief was being considered, and within less than one hour's time, a second dispatch was received announcing the fact that a single pipe and jet had been passed through the hub of the wheel which thus had been pumped 16 ft. below the surface of the sand, entirely out of the way.

All the fixtures for doing this heavy work were of the rudest character, and very inexpensive—everything was done from the decks of two ordinary flat boats, without staging of any kind. The derricks, pumps, and other appliances were of the simplest construction, because the contractor had serious doubts as to the success of the plan, and was unwilling to incur the expense of efficient and well-designed machinery upon an uncertainty. He commenced and carried the work to a successful completion without addition to his immature contrivances.

After the cylinders were sunk to grade they were filled with good shell concrete, deposited through a tube, used somewhat after the manner frequently described in connection with other works in this country; after shrinkage and refilling, a heavy cast-iron cap was bolted over the top of each cylinder, and the piers were complete for the superstructure.

These piers have now been in use about eighteen months, and so far have given entire satisfaction. A uniform scour of about 6 ft. occurred at each pier, in curve shape, extending some 20 ft. from the pier; beyond this distance there was no appreciable disturbance. The bottom around the piers was restored to its normal condition by filling the curve with broken stone.

It is not claimed that this process for sinking cylinders or piles can be advantageously applied under conditions differing very materially from those existing at Tensas, as the resistance was found quite difficult to overcome, when small deposits of clay were encountered; and in the event of striking logs or other hard substances, not discovered before locating the piers, the process offers no reliable plan for removing them Neither is it claimed that the process is new, for it is well known to the profession that many years ago an English engineer resorted to this method of sinking cast-iron piles in the piers of a bridge built over the river Leven for the Ulverstone and Lancaster Railroad Company. During the late war between the States, the Confederate engineers successfully used the process in sinking heavy wooden piles in the Bay of Mobile. In many instances these piles were driven 10 and 15 ft. in the short space of one minute, through a material that could not be penetrated by piles driven in the usual way.

It is believed this method of sinking large cylinders has never before been employed or considered to any extent, and it is now brought before the Society in the belief that it is susceptible of great improvement and enlarged application, and that it is peculiarly valuable because of the rapidity with which piers may be sunk with it.

DISCUSSION.

Mr. Macdonald—The piers, described in this paper, are identical in all essential respects with those invented by the late Samuel B. Cushing, member of this Society, and first introduced to practical notice in the bridge at India Point, Providence, R. I., in 1868. A full description of the method of construction is contained in a pamphlet issued by Mr. Cushing in 1870.

It will be observed that those piers consist of a cluster of timber piles, driven as closely together as possible, in the form of a circle, and enclosed by a cast-iron cylinder, into which is poured a sufficient quantity of concrete to fill all intervening spaces, and completely cover the tops of the piles, the better to protect them from decay above water, and the action of worms below.

We are thus particular in describing the essential principle involved in the use of these piers, as it would appear from the care taken to overcome the difficulties in sinking the encasing cylinders that they, and not the enclosed timber piles, contributed the controlling feature of interest to the undertaking. For all purposes of immediate stability, these cylinders might have been omitted. Their sole object as claimed by the inventor, is by means of the concrete filling to protect the timber piles from decay or deterioration, as must be evident from the present example, when they were driven but 15 ft. into a shifting sand, and rested upon the same material.

We do not agree with the writer of this paper that this system cannot be advantageously used under conditions differing materially from those existing at Tensas—the reason he assigns being that it is difficult to sink the cylinders when deposits of clay are encountered. From what has been said of the office performed by the timber piles, it will at once appear that a stiff clay bottom is peculiarly adapted to the placing of Cushing's pile piers. Into such material, clusters of piles may be firmly driven precisely as he has described at Tensas, and the encasing cylinders may then rest almost upon the surface of the bottom, or at most be settled into it a foot or two by their own weight; an additional security is obtained by placing a few feet of rip-rap around the base of the pier. In the case referred to, at India Point, the cylinders were worked into the mud bottom only about 7 ft., and at the Connecticut river bridge a still smaller distance.

THE FIRELESS LOCOMOTIVE.*

By RICHARD H. BUEL.

From "The Engineering and Mining Journal."

The New York "Tribune" recently, in calling attention to an article on the Fireless Locomotive, said that the inventor of this machine seemed to have taken council of Mrs. Partington, who inquired why they didn't boil their water at home, instead of using these dangerous steam boilers. Considerable attention seems to have been directed to the action of the fireless locomotive of late, and some remarks on the subject may not be devoid of interest. It was patented by Dr. Emile Lamm, of New Orleans, about a year and half ago, and locomotives designed in accordance with his patents are now in regular use on one of the railroads in that city. Two experimental locomotives have been built in this vicinity, and accounts of their trial trips have appeared from time to time in the daily papers. Dr. Lamm was a dentist, without any special education or experience as an engineer, but he devoted considerable time to experiments on prime movers that could be attached to ordinary street cars, in the place of horses. He was desirous of inventing a machine that would be cheap, compact, safe, and easily managed. Unwilling to accept the results obtained by previous experimenters, he put all his ideas to the test of practice. His first attempt was with an electro-magnetic engine. He afterwards experimented with ammonia, and his third plan was to employ a reservoir of water immersed in a tank of chloride of calcium at a high temperature. It was while conducting these latter experiments that he observed that the reservoir of water alone retained its heat for a long time, and as there were many practical difficulties in the use of the chloride of calcium, he finally decided upon the plan which is embodied in the present design of the fireless locomotive.

As now constructed, this consists of a reservoir, or tank, capable of sustaining a high pressure, mounted on wheels, and connected in the steam space to an ordinary

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* A paper read before the Polytechnic Branch of the American Institute.

form of steam engine, the exterior of the reservoir (the steam pipes and cylinders) being protected by coverings from loss of heat by radiation. This reservoir, being partially filled with water, is connected at the lower portion to the steam space of a stationary boiler, and steam is admitted, heating the water and equalizing the steam pressure in the boiler and reservoir. The locomotive is then ready to start, and, if steam is admitted to the engines, will continue to move until the water in the reservoir has cooled down so much as not to be capable of furnishing steam of a working pressure. Suppose, for instance, that on starting, the water in the reservoir has a temperature of 400 deg. Fahrenheit, and that at the conclusion of the run its temperature is 250 deg., corresponding to pressures of about 235 and 15 lbs. per sq. in. above the atmosphere respectively. In this case, each pound of the water would give up 150 units of heat, and each pound of water that was evaporated would require about 970 units of heat for its conversion into steam, so that each pound of water in the reservoir would give out heat enough in cooling down, to make about 0.16 lbs. of steam, or a little more than a cubic foot.

This, in brief, is the theory of the fireless locomotive. It is hardly necessary to point out the advantages of this system. It must be evident that the reservoir, which is not exposed to the action of fire, will probably be more durable and less liable to rapid deterioration than an ordinary boiler. The danger of explosion, when the machine is in motion, is very slight, as the greatest pressure is put upon the reservoir when it is being charged at a station, and this pressure is continually diminishing during a run. There is little chance of danger from the oversight of the attendant, and less skilful engineers being required than in the case of ordinary locomotives, the running expenses can be reduced. In many places where motive power is desired for cars, it becomes a serious question how to dispose of the products of combustion, so that they shall not vitiate the atmosphere. The fireless locomotive solves this problem admirably. It may be that this system is not quite as economical as that in which the steam is generated by the combustion of coal in each separate boiler, and probably this can only be determined by experiment. But by having well designed stationary boilers and careful management at the stations where the reservoirs are charged, it is possible that there will not be much difference in the cost of fuel, between the two systems. In the matter of relative bulk, of course, the preference is to be given to the coal-burning locomotive, since a good boiler is capable of utilizing about 10,000 units of heat from the combustion of a pound of coal, and in the example cited above, the reservoir utilized 150 units from each pound of water. This is not a matter of so much importance, however, in many cases, as some of the other points in which the fireless locomotive seems to possess advantages.

The writer, in company with Mr. Henry L. Brevoort, recently made a trial trip with the smaller of the two locomotives in this vicinity. By the courtesy of the officers of the Company, and particularly through the exertions of the engineer, Mr. Gibson, arrangements were made to take down considerable data. It was impossible, however, owing to the defective nature of the connections, to determine accurately the temperature of the water in the reservoir, or to observe the variations in the water level. It was found that the water was quite unequally heated in different portions of the reservoir, showing that the arrangement for charging with steam was not as complete as was desirable. On starting, the reservoir was half full of water, but the glass gauge having broken, no further observations could be made. A counter was attached to the engines, and the steam gauge was carefully tested before the trial. The run was made from East New York to Canarsie, and back. During the trip, indicator diagrams were taken from the cylinders, in sufficient number, and under such circumstances, as to give average conditions. It is believed, therefore, that the data, although not as full as could have been desired, are quite accurate, and give the fullest particulars of the practical working of the fireless locomotive, that have yet been obtained.

The locomotive with which the trial was made, consists of a platform set upon a four-wheeled truck, carrying a cylindrical reservoir, 37 in. in diameter and 9 ft. long, with a steam dome, 12 in. in diameter and 2 ft. high. The shell of the reservoir is $\frac{1}{4}$ in., and the heads $\frac{5}{8}$ in. in thickness. No braces are used in the construction. The steam drum is connected to a pair of vertical engines, fitted with the link motion, each cylinder being 5 in. in diameter by 7 in. stroke. The reservoir is covered with cement and felting, and the steam pipe and cylinders are also felted. The engine shaft has a pinion of 26 teeth, gearing into a wheel of 46, which latter is secured to one pair of truck wheels, which are the drivers. In charging the reservoir, steam is admitted through a two-inch pipe, running the whole length of the reservoir, and perforated with small holes. The dimensions of the reservoir and cylinders, in cubic feet, are as follows:

Cylindrical portion of reservoir	64.64
Steam dome " "	1.55
Volume of cylinder swept through by each piston, per stroke	0.0786
Clearance and passages, at each end of each cylinder	0.0045

At the commencement of the trip, the pressure of steam in the reservoir was 142 lbs. per sq. in., and at the conclusion it was 22. During the run, the variations in the pressure were as follows:

3.35	142
3.37	132
3.38	124
3.39	124
3.51	102
3.53	97
3.55	89
4.04	70
4.07	66
4.10	52
4.13	48
4.15	44
4.21	29
4.24	22

81.5 mean pressure during run. Several short stops were made during the run, for the purposes of observation and adjustment, and the power exerted by the engines at different points varied considerably, on account of changes in the grade of the road. The total time of trip was 49 min., and the running time 35½. The total number of revolutions of the engine was 5,233, and the average revolutions per minute 147.4. The distance run was 4.4 miles; and average of all the indicator diagrams shows that the mean pressure of steam above the atmosphere, in the cylinders, was 23.01 lbs. per sq. in., and the mean back pressure, 5.15 lbs. The diameter of the piston rods being ¾ of an in., the mean area of each piston is 19.414 in.—and from these data it is found, by a simple calculation, that the mean indicated horse-power exerted by the engines during the run was 3.61. Knowing the volume of steam required for each stroke and the total number of strokes, it appears that the amount of steam accounted for by the indicator was 1739.4 cubic ft. Owing to a faulty construction of the valve motion, it was necessary to run with full link, and regulate the speed of the engines by throttling the steam, so that the steam was wire-drawn, instead of being expanded. The mean terminal pressure of the steam above the atmosphere, as shown by the indicator diagrams, was 19.86 lbs. per sq. in., and as steam of this pressure weighs 0.0846 lbs. per cubic ft., the amount of steam furnished by the reservoir, accounted for by the indicator, was 147.15 lbs. The amount of steam actually used by an engine, however, is generally in excess of that shown by the indicator, and as the protection of the reservoir from loss by radiation was far from efficient, it is probable that the actual evaporation was somewhat greater. It will be easy to calculate how much water would have been evaporated under the most favorable circumstances, viz.: that no heat should be lost by radiation—that the water in the reservoir should be heated, at starting, to a temperature due to a steam pressure of 142 lbs. per sq. in., and should be saturated with an equal volume of steam at that pressure, and that, at the conclusion, the water in the reservoir should have a temperature due to a steam pressure of 22 lbs. per sq. in., and should be saturated with an equal volume of steam at that pressure.

It will be fair to assume the evaporation to take place at a pressure of 82 lbs. per sq. in., a mean between the initial and terminal pressures in the reservoir. Then, at starting, the reservoir would have 1,236.3 lbs. of water, each pound of which contained 361.8 units of heat, and 23.2 lbs. of steam, each pound of which contained 1,224.3 units of heat—so that the total number of units of heat in the reservoir at commencement would be 475,696.6. At the termination there would be 1,236.3 lbs. of water less the amount that had been evaporated, each pound containing 262 units of heat, and 5.92 lbs. of steam, each pound of which contained 1,193.8 units of heat—and calling x the amount of water that had been evaporated, the number of units of heat at termination would be 330, 956.48—262x. The number of units of heat available for making steam would be the difference between the number of units at commencement and termination, or 144, 740.12+262x. Each pound of water that was evaporated would require an addition of 951.1 units of heat for its conversion into steam—and by the solution of a simple equation it is found that the number of pounds of water that would be evaporated, is 210.04.

The reasons for the difference between this result and 147.15 lbs., as calculated from the indicator diagrams, have already been given—and it seems probable that the actual evaporation in the reservoir was about mid-way between these two results.

It will perhaps be a matter of surprise to many, that the working pressure of steam in the reservoir was exhausted in so short a time, and may cause doubts as to the value of this system of locomotion. It should be remembered that the general design and construction of the fireless locomotive that has been described, seem expressly intended to render the best system unsuccessful. It may be worth while, then, to devote a little space to a consideration of the engines. From the evaporation, as shown by the indicator diagrams, it appears that the amount of water required by the engines per indicated horse power per hour, was 68.9 lbs. or 1 1-10 cubic ft.; as already remarked, it is probable that still more water was used. In the time of James Watt, an evaporation of 1 cubic ft. of water an hour was considered a liberal allowance for the production of an indicated horse power in an engine—and the use of so much steam in these engines is evidence of bad design or improper management. It will not be difficult to find reasons for this great waste.

Referring again to the indicator diagrams, it will be seen that the back pressure on the pistons was 22.38 per cent. of the mean pressure in the cylinders. By far the greatest waste occurred, however, from wire-drawing the steam, instead of cutting it off at a proper point, and allowing it to expand during the remainder of the stroke. No argument is necessary to show that an automatic cut-off would be the most economical arrangement for an engine working with a continually varying pressure of steam. A comparison of the average conditions in the two cases—1st, that steam of 81.5 lbs. pressure should be cut off at such a point as to produce a mean pressure of 23.01 lbs. per sq. in. in the cylinder—or 2d, that steam of the same initial pressure shall be allowed to expand without doing work, until its pressure is reduced to 19.86 lbs. per sq. in., the terminal pressure—shows that the waste, in wire-drawing the steam is 99 per cent.—or that, in the case under consideration, if the steam had been cut-off, it would have produced the same effect with an expenditure of 50.25 per cent. of the amount of steam actually required. Hence, with this single change in the arrangement of the engine, all other things remaining the same, the locomotive would have run twice as far.

A new locomotive is now in course of construction, in which more efficient arrangements are made for heating the water when charging the reservoir with steam, a better system of valve gear is applied, and the general design and workmanship are much improved. It is hoped that this machine will demonstrate successfully the merits of Dr. Lamms' system.

It may be interesting, in conclusion, to consider the case of a fireless locomotive under more favorable conditions, but under such as it is believed can readily be realized in practice. Suppose, then, that a reservoir of the same size as the one which has already been described, is filled to the dome, on starting, with water having a temperature due to a steam pressure of 275 lbs. per sq. in., and saturated with an equal volume of steam at that pressure,—that, at the termination, the water is saturated with an equal volume of steam having a pressure of 20 lbs. per sq. in., and has a temperature due to that pressure—that the engines shall be so designed as to develop 4 useful horse power with an indicated power of 5 1-3 (making an allowance of 25 per cent. for friction), using 25 lbs. of water per indicated horse power per hour—and that there shall be a loss from radiation of 5 per cent. of the water evaporated.

Under these conditions, the reservoir would contain, at the commencement, 1,499,754.66 units of heat, and at the termination, letting X represent the number of pounds of water evaporated, it would contain (905,913.82—258.7 X) units — so that there would be (584,840.84+258.7 X) units of heat available for making steam. Each pound of water would require an addition of 966.4 units for its conversion into steam, so that the amount of water evaporated would be 826.4 lbs. The loss from radiation would be 41.12 lbs., and the steam available for useful work, 785.28 lbs.—hence the locomotive would run 5.9 hours before the reservoir required recharging.

It is believed that the foregoing is a fair statement of what may be expected from this locomotive, when properly designed and constructed.

SOLUTION FOR THE BATTLE OF THE GAUGES.

By LEWIS M. HAUPT.

Written for Van Nostrand's Magazine.

FACILITY OF COMMUNICATION IS ONE OF THE MOST IMPORTANT ELEMENTS IN HUMAN PROGRESS AND MATERIAL DEVELOPMENT.

It must be conceded that since a straight line has neither breadth nor thickness, it is the limit of narrow-gauge railways; consequently any road in which the two rails are made to approach each other until their separating distances is zero, that is, until they coincide, must be the *ne plus ultra* of narrow gauges.

That the idea of a zero gauge railway will share the fate of all other important inventions and improvements, in meeting with the popular incredulity, is to be expected, but that it is entirely practicable has been already demonstrated. It is the object of this paper merely to state the facts as they exist, and not to attempt in such limited space and time a satisfactory solution of the problems of cost of construction, repairs, rolling stock, equipment, limits of grades and curves, stability, speed, tonnage, etc.

It will be apparent from a mere description of the road bed and rolling stock that an immense economy will result from its introduction or substitution, that it will render accessible districts which have heretofore been regarded as worthless for lack of communication, and that the degree of its curvature may be so great as to render it absolutely a surface line in a very broken country.

The combination of two rails results in a single "crescent" rail having a weight of about one-fourth that of the two rails ordinarily used, thus reducing the cost proportionally. This rail surmounts the upper edge of a horizontal prism, the right section of which is a right-angled triangle, resting upon its hypothenuse as a base. Dimensions—altitude 12 in., "base 24 in.," area 1 sq. ft. This triangular prism is the trunk or road bed, and may be laid upon the natural surface, supported upon unhewn posts resting on a sub-foundation below frost, or may be elevated to a height of several hundred feet as in crossing deep ravines or gorges. In excavation, therefore, on side hill, the base need be only 2 ft., in through cuts from 10 to 12, to clear the cars and allow side drains, and in embankment or trestle, 2 ft.

The prism may be constructed either of timber, 1 ft. square, cut through its diagonally-opposite edges and turned over back to back; of a square cone of smaller cross section, covered by a 2 or 3-in. plank, spiked on to give the requisite lateral surface (1.4142'), or of 1-in. boards, placed vertically, and nailed to a 3-in. plank as a cone (the requisite level being given by templets). This last form is preferred, as distributing the flaws and joints in the best possible manner, and enabling curves to be turned more readily. The top surface may be protected by cement, paint, or metal covering, as desired.

The rail and trunk are united by spikes or bolts, in the ordinary manner.

Such is the roadway.

Fig. 1 is a section of the roadway and rail.

Fig. 2, an elevation of the same.

This construction requires a corresponding modification in the rolling stock, which has been effected as follows: Instead of the ordinary 4-wheeled truck, one of 2 wheels is substituted, in which these wheels revolve in the same vertical plane, fore and aft, as in a velocipede. These are the drivers or traction wheels which bear on the rail T, and to which the power is attached. Fastened to the bed of the truck and on both sides of the drivers are two axles fixed parallel to the planes (*s s*) by hangers. These axles carry at their lower extremity a cylindrical roller or guide, bearing on the planes *s s*, and at the upper end two conical wheels or guides bearing upon the sides, *t t*, of the rail, and also upon the drivers to prevent the latter from oscillating and thus injuring their journals. The number of drivers may be increased *ad libitum*, thus distributing the weight over any desired length of track. The friction upon the guides is very slight, and varies inversely as the velocity, so that at high rates on straight lines it is practically zero.

Thus, it is seen that, although the centre of gravity is above the point of support, the case is not one of unstable equilibrium, for the base between the guides is 2 ft., which is distributed by the hangers to a bed of 4 ft. in the engine and 7 in the cars.

In the car trucks the wheels project through the axis of the floor, being covered by the seats, which are placed longitudinally, giving side aisles. By this means the floor may be placed as low as the rail itself.

These comprise the principal feature of the improvement, subject to modification to suit requirements.

The objection almost invariably urged is the fear that the rolling stock will run off the track. It will be perceived that to do so the guides on one side must rise at least 1 ft., lifting the weight of nearly one-half the engine or car. This it cannot do, loaded as it is, and the greater the load the greater will be the stability. The only cause for derailment would be from rupture of the guides on the same side, but if their number be increased to three or four, it may never happen that they will all break simultaneously.

Fig. 1.

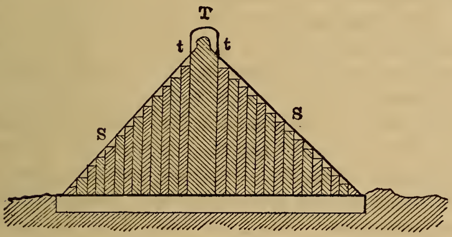
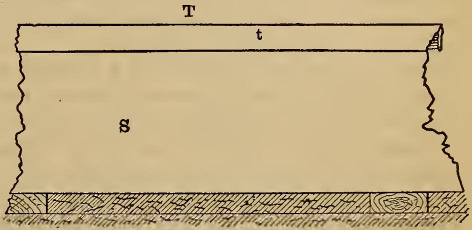


Fig. 2.



The illustration by the inventor, Mr. E. Crew, in his lecture before the Franklin Institute, on the 29th of January, would satisfy the most incredulous on this point. He had a circular prismoidal track of about 4 ft. diameter, constructed as a model. Upon this track he placed a model truck, and having mounted the track upon a vertical axis by giving a circular undulating motion to it, caused the truck to fly around with such rapidity as apparently to shoot across the diameter with greater velocity than a shuttle in a Jacquard loom. This, in itself, was perfectly satisfactory, but the inventor went still further; removing the track from its support and holding it by means of two handles, he gradually inclined its plane to that of the horizon, at the same time keeping up the oscillation so that the truck ran around as before, until it became absolutely vertical, and the truck did not fall off, proving that the force of gravity was neutralized by the inertia of the moving body, as in the gyroscope. A 4-ton engine has run upwards of 300 miles at the Chestnut street rink, in Philadelphia, on a track more than half of which is on a curve of 37 ft. radius. The question of practicability is therefore placed beyond a doubt, and it only remains to add a few words concerning its applications.

As an elevated street railway, it can have no superior, either for economy, quietness, safety or speed. It is admirably adapted to train-towing on canals, filling all the requirements of steam towage with much less power, and without waste or injury to the canal. It may be used as a camel in hydraulic engineering, but its most extensive application will be in mining districts, which are now destitute of the necessary transportation to develop them, or to lumber regions beyond the limits of a paying haul by wagons.

It is destined to become a powerful auxiliary in the hands of railroad corporations as feeders to their trunk lines, and a boon to property owners whose estates lie in districts inaccessible to ordinary railroads.

The cost of construction per mile can be readily computed for different districts from the data given. The simple mechanical details of switching, sidings, crossings, etc., have been satisfactorily arranged, leaving nothing doubtful in the way of its successful introduction.

It will be found of inestimable value to the railroad interests, not only of this country, but of the world.

AN ACCOUNT OF THE ERECTION OF A DRAWBRIDGE WITHOUT FALSE WORKS.*

By C. S. MAURICE, C. E.

In giving the following I would say, by way of preface, that though the matter may not be of sufficient importance to be made the subject of a formal communication to the Society, or to be embodied in its Transactions, yet the fact that the plan of raising was hastily improvised with only the crudest materials at hand for its execution, may serve as some apology for occupying a portion of your time this evening.

The structure to which I refer is the iron bridge built for the Alabama Central Railroad over the Tombigbee river, some six miles below the town of Demopolis. The width of the river here is from 500 to 600 ft. between its banks, and the depth of water varies from 6 or 8 ft. in dry seasons to 60 or 65 ft. at the time of heavy freshets. The first railroad bridge at this point was completed in 1866, and consisted of 2 Howe truss spans of 200 ft. each, and a pivot span of the same dimensions, the whole structure being supported on timber piers. In the substructure of the new bridge, which was built on the site of the old one, brick piers with stone copings were used, and the superstructure consisted of 2 fixed spans of 160 ft. each, with a pivot span of 260 ft., all of wrought-iron.

The construction of the new piers was begun in the summer of 1872, by Col. M. B. Prichard, of Montgomery, Ala., and completed about December 1st following. The contractors for the superstructure, who also removed the old bridge and furnished false work of sufficient strength to carry the trains while the work was in progress, began operations late in October, 1872. The fixed spans of the old bridge were taken down, and the iron spans erected in their place in the usual manner. This occupied till the first week in December, and the river being then at its extreme low-water mark, and with every prospect of continuing so for at least a month to come, the trestles were erected under the old draw for its removal, and by the middle of the month the contractors were ready to begin the erection of the new pivot span.† A heavy rain, however, having set in a few days before, it was deemed advisable to see what its effects would be on the river before trusting the iron upon the false work. The storm continued without interruption for an entire week, and the river rose with great rapidity to a height of 40 ft., bringing down immense quantities of drift-wood.

The trestles were, of course, carried out, and as there was not the slightest probability of the water falling, so as to admit of their being replaced before the following summer, all idea of completing the bridge in the ordinary manner had to be abandoned.‡ The following plan of erecting by the use of temporary trusses was then determined on. Between the pivot and end supporting pier on the west side, and at a distance from the latter of about 25 ft., there was left standing one of the old timber piers of the original bridge, and this being readily accessible from the fixed span by ordinary stringers, the opening which had to be spanned to reach the pivot pier was reduced to 95 ft. Two light timber trusses, of the Pratt system, 98 ft. in length, were then framed and erected on the river bank, and each one launched separately and floated into position between the pivot pier and timber pier just mentioned.

In the meantime the river had fallen considerably, so that the height from the surface of the water to the top of the piers was about 45 ft.; the trusses were raised from the water by means of tackles and gears and two stout gin poles, and secured in the position they were to occupy. The west half of the draw and the gallows frame were then erected without difficulty. On the east side, however, there was nothing that could be used as a support for the temporary trusses between the new piers, and the distance between them being 114 ft. in the clear, the trusses were about 20 ft. too short to reach across. To reduce the opening so as to admit of using the same trusses, a heavy timber platform, 20

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* Transactions of American Society of Civil Engineers.

† It might be continued that during the season of low water there was no occasion for opening the draw, as the largest boats on the river could readily pass under the fixed spans without lowering their smoke stacks.

‡ It may be asked why the draw was not erected in its open position, at right angles to the line of the bridge. The reason for not doing so was, that no "protector" had been built, and as the nature of the river bed almost precluded the driving of piles, the cost of erecting trestle work capable of resisting the force of the current and the drift, during the rise of the river, would have been so great as to render this plan objectionable on account of the expense.

ft. in length, was thrown out from the pivot pier, the outer end being firmly supported by suspension rods from the top of the gallows frame. The timber trusses were then hung from the upper chords of the completed iron trusses of the west section, and moved forward over the pivot pier until one end projected some 20 ft. beyond the timber platform.

It was in this transfer of the trusses that the principal difficulty was encountered, and the want of wire rope and other suitable appliances for handling heavy weights was most seriously felt. The trusses when detached from each other were, of course, exceedingly limber, and great care was necessary in moving them to prevent injury by buckling.

A Manilla cable, 4 in. in diameter, was stretched from the top of the gallows frame to the top of the fixed span on the opposite side, and on this it was designed to suspend the trusses, one at a time, while moving them into their final position; the height of the cable above the top of the piers and its angle of inclination being such, that it was supposed that the trusses, when hung upon it, would move readily under the influence of gravity.

Unfortunately, however, the cable had been thoroughly wet by a heavy rain, and though the stretch was thought to be pretty well taken out by tackles, the effect of the soaking proved much more serious than was expected. As the weight of the truss came upon the cable it gradually stretched and sagged down some 70 ft., so that the truss, instead of being held above the level of the copings, was about 30 ft. below them.

The plan of transferring by cable having thus proved a failure, the gin poles and tackles were again resorted to, and by means of them the trusses were finally drawn up to their place, one end resting on the east end pier and the other on the timber platform above described. As soon as the timber trusses were connected by putting in the floor beams and laterals, the erection of the iron trusses of the east section of the draw was begun, and in two days —20 working hours—from that time the bridge was completed and the draw opened for the passage of boats.*

The expense of erecting in the manner described proved rather less than was anticipated. The materials for the temporary trusses cost about $200, and the entire work of raising the pivot span, including the framing, raising and transferring of the timber trusses, was accomplished by a force of 18 men in 24 working days, so that the entire cost of erection did not much exceed $1,300.

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* During the erection of the east section of the draw, the river being so high that boats could not pass under the bridge, navigation at this point was pretty effectually closed, and in anticipation of this event, on complaint of the steamboat owners of Mobile, notice had been served by the United States authorities, forbidding any prosecution of the work that would prevent the free passage of boats. To avoid the annoyance of a number of suits at law, a compromise was effected between the contractors and the several steamboat companies, by which the former agreed to pay a fixed rate per day for every day that navigation should be obstructed. The claims for damages on this account, amounting to $3,000, were paid by the contractors on the completion of the bridge.

CONSIDERATIONS RELATING TO SAFETY IN MANUFACTURE AND IN STORAGE OF THE MORE IMPORTANT EXPLOSIVE AGENTS.*

The degree of safety with which explosive agents may be manufactured is an important question connected with their extensive application. The fact that the manufacture of gun-cotton as now carried on involves not the slightest risk of explosion up to the final stage, when the material has to be dried, distinguishes it from most other explosive agents. In gunpowder manufacture liability to explosion exists throughout all operations, from the point when the ingredients are mixed; and with regard to nitroglycerine and its preparations, it appears that, up to the present time, occasional severe accidents during manufacture have been inevitable; they probably arise chiefly from occasional neglect by the workmen of essential precautions in dealing with the explosive liquid, and it is difficult to see how they are to be effectually guarded against. The immunity enjoyed by gun-cotton is due to its being wet, and therefore absolutely uninflammable, throughout all stages, even after it has been compressed into cakes or disks. At this point it contains 15 per cent. of water, the expulsion of which by desicca-

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* From the Minutes of the Proceedings of the Institution of Civil Engineers (English).

tion is unattended by any liability to explosion, or even to ignition, if simple precautions are adopted. For storing large quantities with absolute safety, it is convenient to preserve the compressed gun-cotton in the damp condition as it is delivered from the presses. It has been thus stored for long periods without the slightest detriment; and its non-inflammability in this condition is aptly illustrated by the fact, that the perforations required in some of the charges are produced by drilling the damp gun-cotton, the drill used revolving at the rate of about 600 revolutions per minute. The gun-cotton employed in some extensive experiments recently made on the South Coast had been stored damp for nearly nine months, and was dried partly in the open air, and partly in a hot-air chamber, when required for use. On that occasion 6 cwt. of the damp gun-cotton, packed in 24 strong wooden boxes, was stacked in a wooden shed, and surrounded by inflammable material. The building was then fired, and soon burned fiercely, which it continued to do for about half an hour, when the fire gradually subsided, and the building and its contents were entirely consumed. The gun-cotton must have burned slowly as the surfaces of the masses became sufficiently dry, as at no period of the experiment was any burst of flame, due to rapid ignition, perceptible.

The possibility of extensively employing an explosive compound or mixture as a substitute for gunpowder, without special risk of casualties, is most intimately connected with the question of its stability. Mixtures of saltpetre or chlorate of potash with oxidizable substances of stable character may be generally relied upon to equal gunpowder in their unalterable nature under all conditions of storage and use in different climates; deterioration in explosive power by the absorption of moisture is the only prejudicial result which generally attends long-continued keeping of such mixtures. There are a few instances, however, in which absorption of moisture may in time establish slight chemical action between the components of such mixtures, and thus become not only the cause of more serious deterioration, but also a source of danger, as chemical activity, once started in preparations of this kind, may gradually increase, being promoted by the heat developed, until it attains a violence resulting in the spontaneous ignition or explosion of the mass. Instances are on record of the spontaneous explosion from this cause, of damp mixtures containing chlorate of potash, which have long been known to be perfectly stable when dry. Substances of organic origin, the stability of which is uncertain, require application with much greater caution to the production of explosive mixtures, as it is possible that changes may occur spontaneously in such substances, or may be established by natural atmospheric fluctuations of temperature, which may eventually give rise to an action between these materials and the oxidizing agent with which they are mixed, resulting in ignition or explosion.

Although the stability of compounds which are themselves endowed with explosive properties may appear perfectly reliable when they are in a chemically pure condition, it is susceptible of being seriously affected by comparatively minute causes; hence, the most scrupulous care in the production and purification of such substances is imperatively necessary. In this respect they compare disadvantageously with gunpowder, as a want of care in its production, though it may lead to accident during manufacture, or to an inferiority of the product, will not affect the stability of the material.

Both nitroglycerine and gun-cotton, when prepared in small quantities and carefully purified, have been long known by chemists to be subject to very gradual chemical changes when exposed frequently to sunlight, and also to be liable to slow or rapid decomposition if exposed to temperatures considerably higher than occur as extremes under natural conditions in any climate. Both substances are also well known to have exhibited great stability under normal conditions of preservation, and even when continually exposed to light; but though many specimens exist which have remained unaltered almost since their first discovery a quarter of a century ago, the instances are numerous in which laboratory specimens have undergone spontaneous change with more or less rapidity.

The apparently variable nature of those substances is due to the retention by them, in some instances, of small quantities of impurities, comparatively unstable in their character, derived from foreign matters in the cotton or the glycerine; exposure to a high temperature or to sunlight may develop changes in them, resulting in the production of acid matters, the development of which may lead to the establishment of chemical change in the nitroglycerine or gun-cotton; hence they may constitute the germs of decomposition. Such impurities would be, to some extent, enclosed in the hollow fibres of gun-cotton, and can then only be removed effectually by a breaking-up of the latter, and long-continued washing; in nitroglycerine they would be held dissolved by the substance, and their removal can also be only effectually accomplished by reducing the liquid to a very fine state of division, and submitting it to protracted washing, with the aid of alkaline agents.

For many years nitroglycerine was universally regarded as specially liable to spontaneous change. Even samples of different quantities of several pounds each, which, within the last four years, were produced at Woolwich in immediately successive operations, all apparently under the same conditions and with the special object in view of obtaining a thoroughly purified and stable material, have exhibited great differences in their keeping qualities. They have all been preserved in the dark, side by side; some are now in their originally pure condition, others have become more or less strongly acid, and two or three have undergone complete metamorphosis into oxalic acid and other products. The manufacturing and purifying processes, as perfected by Mr. Nobel, appear to furnish more reliably uniform products than those usually obtained on a small scale; and such specimens of these products as Mr. Nobel has had an opportunity of examining have exhibited great stability. Yet, if it were possible to trace accidental explosions to their cause more frequently than is the case, an exceptional want of stability might perhaps have been found, in some instances at any rate, auxiliary in bringing about the violent nitroglycerine explosions which have occurred. It has, however, been already established, by extensive experience during the last three years, that nitroglycerine is a far more reliable material than was formerly believed, and that if the most scrupulous attention is paid to the purification, and is combined with vigilance during storage and use, and the adoption of certain precautions which have already been proved important safeguards against chemical change in materials of this class, the risk of accident is so greatly reduced as to warrant the extensive manufacture and employment of nitroglycerine preparations under restrictions similar to such as may be deemed sufficient in the case of other explosive agents.

The extensive experiments and observations which were set on foot nine years ago by the Government Committee, and have been continued to this day, on the keeping qualities of gun-cotton prepared by the Austrian process, have furnished most satisfactory results. Considerable quantities of gun-cotton, in a great variety of forms, have been stored at Woolwich for several years, and their periodical examination has failed to afford any reason whatever for doubting the stability of gun-cotton under all conditions of storage which are likely to occur. The experience thus gained applies even more favorably to gun-cotton reduced to pulp, according to the system lately in use, whereby the uniform purification of the substance is more effectually secured. Compressed gun-cotton has not only been stored extensively in different parts of Great Britain, but it has also been exported in considerable quantities to Australia, the West Indies, India, South America, and other distant countries, and has been used under circumstances specially trying to any material of uncertain stability.

The explosions which occurred at Stowmarket, ten months ago, had the natural effect of dispelling from the public mind the great confidence which was becoming very generally entertained in the stability of gun-cotton. Fortunately, the facts which were elicited in the course of the inquiry constituted so complete a chain of evidence as to place the first cause of the explosion beyond any reasonable doubt, and to demonstrate that it was quite independent of any want of stability of the properly manufactured material. A supply of gun-cotton delivered from the works at Stowmarket, forming part of a quantity of which there remained a store in the magazines that exploded, was found to contain a proportion of disks in a highly impure condition. The amount of free (sulphuric) acid existing in some of these disks was so considerable that it could not possibly have been left in the gun-cotton after the first rough washing which it receives immediately on removal from the acid, and before conversion into pulp in the rag-engines, where it is beaten up for several hours with a large volume of water. Supposing, therefore, that the gun-cotton-pulp composing these disks had been submitted to the compressing process without being passed through the intermediate and principal purifying operation, it could not possibly have contained even a small proportion of the sulphuric acid which was disovered in the impure disks; and the same would have been the case even if the unpulped gun-cotton, after the preliminary washing and wringing, could have been converted into compressed disks. It was indisputably established, therefore, that the sulphuric acid discovered in the impure gun-cotton, and which could not have been generated by any decomposition of the substance, must have found its way into the finished material in some manner totally unconnected with the process of manufacture, and that no amount of carelessness in manufacture, even to the extent of partial omission of the purifying processes, could have led to the existence of the acid found in the impure substance. That this impurity was sufficient to establish rapid change was sufficiently proved by the condition of some of the disks; and that this chemical change, accelerated as it was by the great heat of the weather at the time, gave rise to a development and accumulation of heat inevitably culminating in the ignition of some portion of the stored gun-cotton, was readily demonstrated by simple experiments with some of the impure disks themselves. But although the ignition of the store of gun-cotton in the lightly-built magazines at Stowmarket was completely accounted for, the very violent character of the explosions, and especially that of the second explosion of a small store which was burning for a considerable time before its contents detonated, were results quite unexpected to those well acquainted with the properties of gun-cotton in the compressed form.

Many practical experiments had demonstrated that it might be submitted to extremely rough treatment without any risk of its explosion; and single packages of the closely-confined material had been repeatedly ignited, from within and without; no other result than an inflammation and a rapid burning of the gun-cotton having ever occurred. These demonstrations of the apparent immunity from explosive properties of compressed gun-cotton, unless strongly confined or fired by detonation, appeared to be fully confirmed by the results of a somewhat extensive experiments made at Woolwich a year ago, with gun-cotton packed in firmly-closed strong wooden boxes of the kind which Government proposed to use for storing the material. Eight such packages, each containing 28 lbs. of gun-cotton, were enclosed in a pile of similar boxes loaded to the same weight, and the contents of the centre box were ignited. No explosion resulted, and the contents of some of the boxes even escaped ignition. A second experiment, in which the centre box was surrounded by inflammable matter, so that a fierce fire burned within the heap for many minutes before the gun-cotton ignited, was also unattended by any approach to an explosion. The apparently conclusive nature of these experiments undoubtedly encouraged a false confidence in the non-liability to explosion of stores of gun-cotton in the event of accidental ignition; and the catastrophe at Stowmarket demonstrated the imperative necessity for a more extensive investigation of the subject.

The results of some experiments recently instituted near Hastings, by the Government Committee on gun-cotton, have already served to throw great light upon the manner in which the explosions at Stowmarket were brought about. In the first instance, twenty-four boxes (containing 6 cwt. of gun cotton), of the kind used in the Woolwich experiments, were stored upon tables in a small wooden shed of light structure, and a heap of shavings and light wood was kindled immediately beneath the boxes, two of which were left partly open. After the fire had been burning for about seven minutes the gun-cotton inflamed, and continued to burn with rapidly increasing violence for nine seconds, when a sharp explosion occurred. A very similar result was furnished by a second experiment, in which the same number of boxes of gun-cotton were stored in a small magazine of stout brickwork. By subsequent comparative experiments it was judged that a considerable proportion of the gun-cotton had burned in both instances before the explosion occurred; but these were nevertheless of such violence as to produce large craters in the shingle on the site of the buildings, and to project the debris with much force to considerable distances. Two repetitions were afterwards made of the first experiment, in wooden sheds of similar structure, with corresponding quantities of gun-cotton, similarly arranged in boxes of the same size, and fastened down, just as securely as those in the former experiment; but the boxes were made of somewhat thinner wood, and were constructed less strongly. In neither of these experiments did an explosion occur. In the one instance the fire was burning in the building for more than half an hour before the gun-cotton became ignited, and, three minutes after the first great blaze had subsided, there was a second blaze of gun-cotton. Although the latter must have been exposed to intense heat, no explosion was produced. In the second experiment, the gun-cotton burned in three successive portions, the last having been exposed for many minutes to a fierce heat, yet burning non-explosively.

The first two of these experiments demonstrated that if, in a store containing packages of gun-cotton in somewhat considerable number, the material became accidentally inflamed, the intense heat developed by the burning material in the first instance might raise some portion, still confined in boxes, to the inflaming point, and that then, the mass of the confined gun-cotton being in a heated condition, the ignition would proceed with such rapidity as to develop the pressure essential to explosion while the gun-cotton was still confined, the resulting explosion being instantaneously transmitted to other boxes. When the magazines at Stowmarket exploded, a large volume of flame was observed to precede the explosion by a distinct interval. The two other experiments described appear to demonstrate that with such quantities as were stored in the experimental sheds, the fact of the material being confined in boxes of comparatively light structure constitutes a safeguard against explosion, the reason being that the weaker packages are opened up by comparatively feeble pressure from within; hence, when the contents of a box become raised to the inflaming temperature, or become ignited by the penetration of flame to the interior, the pressure developed by the first ignition is not sustained by the box to a sufficient extent, or for a sufficient time, to bring about explosion.

On the occasion of the Stowmarket accident there were two store sheds, containing gun-cotton packed in boxes of light construction, which were ignited by the first explosion, and burned out without exploding; while a third, which contained gun-cotton packed in the strong Government boxes, exploded with great violence, after having been in flames for some time.

Simple experiments serve to demonstrate that if any explosive compound or mixture be ignited when in a heated condition, it will burn with a violence proportionate to the temperature to which it has been raised. If this be near the exploding point, the result must be an explosion which will be violent in proportion to the degree of confinement of the material. A practical demonstration of this was furnished by an explosion which occurred at Woolwich in 1866.' Several strong packages (metal-lined cases), filled with von Lenk's gun-cotton, some of which was purposely left impure, had been exposed for seven months to artificial heat in a strong brickwork chamber heated by steam. The impure gun-cotton in some of the packages was then known to be in a decomposing state, but the experiment was continued, and eventually spontaneous ignition occurred at a time when the boxes were heated to the maximum temperature. The result was a violent explosion of all the packages; the very strong confinement, and the heated condition of the gun-cotton which ignited, added to its being at the time in a state of chemical activity, determined its explosion, and the explosion of the other packages was a necessary consequence of the violent concussion to which they were exposed.

There can be no doubt that the results of the recent experiments and of those made last year, as also the results of the Stowmarket accident, have to be considered in relation to the quantities of gun-cotton operated upon, as well as to its confinement. The confinement of the eight strong packages by the layers of boxes which surrounded them on all sides, in the Woolwich experiment, was probably quite as great as that afforded by the light and roomy shed in which twenty-four boxes of the same kind were placed in double layers, in the South Coast experiment; yet in the latter case an explosion was developed, and not in the former with the smaller quantity. In the South Coast experiments, with 6 cwt. of gun-cotton, the explosions occurred 8 sec. and 10 sec. after the ignition of the gun-cotton; in the Stowmarket magazine, where several tons of gun-cotton were stored, the explosion appears to have almost immediately followed ignition; it must be borne in mind, however, that in this case much of the gun-cotton was closely confined by the large number of surrounding packages, and that the temperature of the gun-cotton was already raised considerably throughout by long continued hot weather. Both of these circumstances must have greatly favored the rapid development of explosion, independently of the much more intense heat generated by the rapid spreading of fire through a large proportion of the gun-cotton. The satisfactory results obtained in the South Coast experiments with the lightly-constructed boxes, with employment of 6 cwt. of material, appear to have received confirmation from the result of an accident which occurred in 1869 at Penryn, when a magazine of brickwork containing 20 cwt. of compressed gun-cotton, packed in boxes of light structure, was burned down without any explosion. But it is, nevertheless, very possible that a similar result would not be furnished by several tons of gun-cotton similarly packed; the much higher temperature which would be developed in that case by the first spreading of the fire, and the additional confinement, due to the larger number of packages, might combine to develop conditions favorable to the violent explosion of some portion of the mass, though no doubt a much larger proportion would burn non-explosively than if strong boxes were used. While, therefore, in strong dry gun-cotton, the probability that violent explosions will result from the accidental ignition of a magazine may be considerably diminished, or, at any rate, the violence of a possible explosion may be much reduced, by storing the material in packages of which some portions will yield readily to pressure from within, or by adopting any other storage arrangements whereby the rapid penetration of flame or heat between the compressed masses is promoted, it must be considered as conclusively established by the last twelve months' experience, that such regulations as experience and prudence have rendered essential in connection with the storage of gunpowder and other explosive agents, must also apply to the storage of compressed gun-cotton when in the dry state.

FAIRLIE ENGINE FOR THE MEXICAN RAILWAY.

From "Engineering."

The practical development of the Fairlie system of locomotive has just been advanced one step further by the completion of another engine for the Mexican Railway. This is the fifteenth which has been built for that line, upon which the system was originally introduced some two years since by Mr. G. B. Crawley, whose firm are the contractors for the Mexican Railway. In taking the step he then did, Mr. Crawley encountered strong opposition, which, however, he finally overcame. The results of working bear ample testimony to the soundness of his judgment, inasmuch as a saving of 50 per cent. in cost of maintenance of the road is reported to have been effected on that portion of the line worked by the Fairlie locomotives. The engine to which the present notice refers was built by the Yorkshire Engine Company, and with it some interesting and conclusive trials were made yesterday week. The experiments were undertaken at the request of the Directors of the Mexican Railway, and by the courtesy of Mr. Charles Sacré, the locomotive superintendent of the Manchester, Sheffield, and Lincolnshire Railway, they were carried out on the Dropping Well Incline of the South Yorkshire Railway. A number of engineers and other gentlemen directly interested in railways, attended the trials, and among them were Mr. G. B. Crawley, Mr. S. W. Johnson, locomotive superintendent of the Midland Railway, Mr. W. Roebuck, Messrs. Ramos Brothers, of the Lima and Pisco Railway, Mr. W. J. Hammond, of the San Paulo Railway, Brazil, Mr. James Young, of the East Indian Railway, Mr. Harry Stanger, representing the Crown agents for the colonies, Mr. Robert May, Mr. Alexander, formerly of the Mont Cenis Railway, Captain Hobson, etc. Mr. Fairlie is at the present time engaged on professional matters in South America in connection with the narrow-gauge railways there constructed, and working on the Fairlie system, as well as others in course of construction. He was, however, represented at the trial by Mr. Royce, his manager. The experiments were arranged, and personally superintended, by Mr. E. Sacré, the managing director of the Yorkshire Engine Company.

The engine in question, which has been named the "Hildalgo," is of the double-bogie type, and is very similar in construction to one for the Iquique Railway, which will be found described and illustrated in our issue for Nov. 14, 1873. A few leading particulars will, therefore, be all that is necessary upon the present occasion. The engine has four 16 in. cylinders, with 20 in. stroke, a collective heating surface of 1,729 sq. ft., and a grate area of 29 sq. ft. The capacity of her water tanks is 2,000 gallons, whilst her bunkers will contain 30 cwt. of coal, and her crates 400 cubic ft. of wood fuel. She is carried on twelve wheels, 3 ft. 6 in. diameter, all coupled, and her weight in working order is 62 tons. All the wheels being coupled, the whole of her weight is available for adhesion. With a mean cylinder pressure of 90 lbs., the tractive force at the rails is 21,940 lbs., and 24,200 lbs., with 100 lbs. mean pressure. Like those which have preceded her on the Mexican Railway, she has been designed for working the 4 per cent. gradients (1 in 25) on that line. In view of this, she has been fitted with a Chatelier steam brake, besides which she carries a Westinghouse air brake. Another noteworthy feature in this engine is the arrangement of the boiler tubes, the upper rows of which are inclined downwards from the firebox to the smokeboxes, the result being that even when the engine is on the steepest gradient the tubes are always well covered with water. The top of the boiler being raised high over the firebox, a large steam space is formed, from which the steam is taken perfectly dry, no matter at what angle the water may be standing in the boiler.

The branch line on which this engine was tried is known as the Dropping Well Incline of the South Yorkshire system. This is a single line of 2¼ miles long, 1,880 yards of this length being on a gradient of 1 in 50, while the ruling gradient, which is about a quarter of a mile in length, is 1 in 32. Curves of 7 chains radius occur on the line, two of them being S curves, and one of these latter being situated on the ruling gradient. At the summit are situated the Grange Collieries, which in fact the line serves, the junction with the main line being near the Grange-lane Station. The train with which the first run was made consisted of the engine, which weighed 62 tons, twenty loaded coal wagons weighing 275 tons, a composite carriage, two goods brake vans, and two luggage vans weighing 48 tons, and fifty passengers, whose weight may be taken at 3 tons, the gross load moved being therefore 388 tons. At 11.30 A. M. the "Hildalgo" started at the foot of the incline and on the gradient of 1 in 32 for 1¼ mile to push this train before it up to the collieries, the pressure gauge recording 112 lbs. The reason why the train was pushed was in order to guard against the possible contingency of a coupling giving way, which with the engine hauling, would have allowed the detached wagons to have run back on to the main line, and thus perhaps to have added another to the long list of recent railway accidents. Owing to a frost which had covered the rails with rime, and which was followed by a warm sunshine, but which had partially thawed just before the trial, and to the comparatively low steam pressure with which the engine had started, the progress of the train was but slow. The "Hildalgo" slipped considerably, until at length she came to a stand on a gradient of 1 in 32, and a curve of 7 chains radius. This took place 12½ min. from the time of starting, and the pressure gauge showing 110 lbs. In 7½ min. more she was blowing off at 140 lbs., and she then made a fresh start, stopping for 1 min. by signal when near the collieries, and reaching the top of the bank in 28 min. from the time of starting, including stoppages, and showing 135 lbs steam. A few minutes later the train was dropped down the incline to the junction, both the Westinghouse and Chatelier brakes being used to retard the impetus of the moving load of nearly 400 tons.

The train was then run back to the Yorkshire Engine Company's Works at Meadow-lane, where two loaded wagons were detached, reducing the gross load to 365 tons, including the engine. With this reduced load the second run was commenced from the same starting-point as previously, the engine pushing the train before it. A fair start was made with the gauge at 140 lbs., which had fallen to 115 lbs. when the train had reached the top of the grade of 1 in 32 and entered upon that of 1 in 32, a mile and a quarter up the incline. In 9½ min. from the time of starting the train had reached the top of the bank with 110 lbs. steam, after having made a very steady run at the rate of 14.2 miles per hour. The only incident of note on the ascent was a slight slipping of the rear bogie when the engine entered upon the grade of 1 in 32. The train was then dropped down the incline on to the main line, and was run thence back to the Yorkshire Engine Works, having performed her allotted task in a manner as satisfactory as it was convincing to all present. In fact, no better proof could have been desired of the capability of the Fairlie system. The engine was driven by Mr. J. Sharpe, of the Manchester, Sheffield, and Lincolnshire Railway, and her capacity for work is best shown by comparing the results of the trials with the usual practice on the Grange Colliery branch. There the ordinary load for a six-wheeled coupled goods engine is 97 tons, the weight of the engine and tender being 48 tons. It will thus be seen that the results attained by the "Hildalgo" are very successful, and are rendered all the more remarkable from the circumstance that she had to push a long train up steep inclines and against exceptionally sharp curves, the most trying conditions that could be imposed. The experiments satisfactorily prove the advantages which the system possesses for working the present heavy mineral traffic on many main lines. The number of trains would be reduced by about one-half, the chances of accidents being diminished in the same proportion.

On alighting from the train at the Meadow Hall station, the visitors proceeded to inspect the works of the Yorkshire Engine Company, over which they were conducted by Mr. Edward Sacré There they found amongst other machinery in hand a number of Fairlie locomotives in various stages of progress for foreign railways.

REPORTS OF ENGINEERS' SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—*January* 21*st*, 1874.—A stated meeting was held at 8 o'clock P. M. The subject for consideration, "Tests of Materials used in Construction and Testing Machines," was announced. Communications, and the following papers in response to the circular sent out, inviting discussion, were presented: "Experiments on the Tensile Strength of Bar Iron and Boiler Plate," by Charles B. Richards, M. E.; "Proportions of the Heads of Eye Bars," by Charles Macdonald, C. E.; "Tests of Wrought-Iron Beams and Rods," by T. Guilford Smith, C. E.; "Tests of Bridge Irons," by Gen. W. Sooy Smith; "Effects of Cold on Iron and Steel Rails," by A. D. Briggs, Esq., and "Experiments on Steel Wire," by Thomas C. Clarke, C. E.

The papers, "Experiments on the Tensile Strength of Bar Iron and Boiler Plate," "Proportions of the Heads of Eye Bars," and "Tests of Bridge Irons," were read and discussed.

Descriptions of the hydraulic weighing apparatus of Mr. Albert H. Emery, and of various testing machines in use, were given, after which, inquiry was made into what should be sought for in testing materials.

February 4*th*, 1874. A communication from Hon. William J. McAlpine, affirming the propriety of engineers making charge, the same as other professional men, for advice given, and one from Prof. Estevan A. Fuertes, asking the Society to declare what should be the course of instruction in schools and colleges, for students of engineering, were read. The latter was referred for consideration and report to a committee, consisting of Prof. De Volson Wood, Mr. Charles Macdonald and Prof. George W. Plympton.

Prof. Robert H. Thurston read a paper entitled "Researches on the Resistance and the Physical Properties of Materials," illustrated by his machine for making graphic tests of the torsional strength of materials; which, with its manner of working, was exhibited, and samples of tests made were shown. Consideration of this paper was deferred to the regular meeting to be held on April 4th, and by vote Prof. Thurston was thanked for the clear, novel and able presentation of the subject made.

AMERICAN INSTITUTE OF MINING ENGINEERS.—MEETING OF THE MINING ENGINEERS.—The first meeting of the tenth session occurred on Tuesday evening, February 24th, at the rooms of the Geographical Society, in Cooper Institute, New York. Only a small fraction of the whole number of members were present, probably not more than 25 or 30 being at the meeting, but among these were gentlemen from the Eastern, Western, Northern, and Southern States. Rossiter W. Raymond, the President, occupied the chair. The meeting was opened with an address by President J. A. P. Barnard, of Columbia College.

On Wednesday they made their excursion to the Ringwood and Sterling mines, in Passaic County, N. J.

At 10 o'clock, Thursday, the Association again met in the Cooper Institute. The following papers were read: "The Bruckner Revolving Roasting Furnace," by J. N. Locke; "A Direct Process for the Production of Iron," by Thomas S. Blair, of Pittsburg; "Exploration by Means of the Diamond Drill," by Oswald J. Heinrich, of Midlothian, West Va. It being two o'clock when the last paper was read, the meeting was adjourned for an hour.

Mr. Heinrich's paper was discussed at the reassembling of the Convention at 3 o'clock, after which Eckley B. Coxe, of Drifton, Penn., made some remarks on "Improvements in Measuring in Mine Surveying;" Edmund C. Pechin, of Dunbar, Penn., followed Mr. Coxe with a short paper on "An Explosion at Dunbar Furnace." The last paper of the afternoon session was on "The Coal Deposits of Hocking Valley, Ohio," by Dr. T. Sterry Hunt, of Boston. It was 5 o'clock when the discussion of Dr. Hunt's paper was concluded, and an adjournment was then had to 8 P. M.

The whole of the evening session was devoted to the reading and discussion of two long papers—one by Prof. John C. Smock, of New Brunswick, N. J., on "The Magnetic Iron Ore of New Jersey," and the other by J. M. Adams, on "The Crushing and Treating of Gold and Silver Ores."

The members resumed their session on Friday morning. A paper which was begun on the previous evening, on "The Crushing and Amalgamation of Ores," was read by J. M. Adams, of Silver City, Idaho.

In the absence of Dr. Thomas M. Drown, his paper on "The Determination of Sulphur in Pig Iron and Lead" was read by the Chairman. In it were described various methods of determining the amount of sulphur in each of these two metals. One method was by mixing borings of the metal with muriatic acid and passing the gaseous vapor through a solution of lead or silver, which precipitates the sulphur; it could also be precipitated by using, instead of silver or lead, a solution of the permanganate of potash. A paper which had been prepared by J. F. Blandy, who was absent, on the "Stamp Mills of Lake Superior," was also read by the Chairman. It was then resolved that the next meeting of the Society should be held in May, in St. Louis.—*Abstract from N. Y. Tribune's Report.*

IRON AND STEEL NOTES.

Alloy of Iron and Manganese.—If one mixes small pellets, filings, or turnings of wrought iron, of cast iron, or of steel, or any other scraps of cast iron, wrought iron, or steel, with minerals containing manganese, tungsten, or titanium, or many of these metals mixed, or with quartz; these minerals or quartz finely powdered, and introduced in suitable proportions for the required alloy; if this mixture be watered completely and regularly throughout with an ammoniacal solution, or a slightly acid solution; if this compound, says the "Chronique de l'Industrie," compressed by hand or mechanically, be shut up in an iron mould, it produces a great development of heat, and at the end of some hours, on opening the mould, a compact mass is found, very hard, that can be broken in a mortar into fragments of any required size. These fragments are perfectly stable up to a red heat, and only disengage at the point of fusion of cast iron. Their treatment in a suitable furnace gives alloys containing iron and manganese in all proportions, from 25 per cent. to 50 per cent. of this latter metal, of silicates of iron containing up to 22 per cent. of silica, and also of alloys of iron and tungsten or titanium, or again triple alloys of these different metals. But these results cannot be obtained but at very high temperatures, that is to say, it is necessary to construct apparatus in which one can use a blast of a very high temperature and pressure.

Under these conditions, and in presence of energetic bases, the furnace is rapidly attacked, principally in the lower parts. It is, therefore, necessary to construct it in the following manner: The furnace is composed of a chamber of refractory bricks, as hard as possible, in which alumina predominates, of a material composed of lime, of manganese, or of pure alumina, and of a hearth composed of carbon, lime and manganese. The blast is heated at least to 35 deg. C., and its pressure ranges to about 13 to 15 centimetres of mercury.

Apropos to this new alloy which the Terre-Noire Company are manufacturing, it will not be, perhaps, without interest to recount the essays tried in this direction to obtain certain qualities of iron that are actually sought, and which, it appears, should be produced under these conditions. The ferro-manganese has been produced, up till now, by two methods—the first is due to Prieger, and is made in crucibles; the second is due to Henderson, and is made in a regenerative furnace. These two methods are founded on simultaneous reduction, in the presence of finely-divided carbon, of a mixture of minerals of iron and of manganese, powdered. The presence of iron in the mixture determines the complete reduction of the oxide of manganese, and it is indispensable for this reduction.

One knows how difficult it is to obtain metallic manganese in laboratory researches, and how a complete reduction of an oxide of manganese by carbon alone requires time and fuel, on account of the pulverulent condition of the mixture, and of the poverty of the flux, which ought to contain an excess of carbon. These two methods can only give but small quantities of alloy daily, and at the cost of an enormous consumption of fuel. There is room, then, to seek a more practicable method from these two points of view, acting in a continuous manner, producing a more complete and simultaneous reduction of the oxides, and their following fusion. With this view, there has been constructed a vertical apparatus similar to a cupola furnace, and into it are introduced the minerals of iron and manganese. Castings have been produced containing, in these circumstances, as much as 18 per cent. of manganese; only it appeared that the special minerals for this product are so rare that the manufacture could not be continued(?). Other essays have been made in this direction in the form of bricks, of amalgamations, etc., but nothing has succeded in this way. Now, one of these special alloys is assuredly much used in England; it contains, according to the analyses, 30 per cent. of manganese, 5 per cent. of iron, and 5 of carbon. Now, it is with the object of arriving at such a production, that the company of Terre-Noire has undertaken its essays, and pretends to have succeeded.

RAILWAY NOTES.

Speed on Narrow Gauge.—One great objection has been made to the 3-ft. gauge roads, that passenger trains must be run at a very slow rate. This objection is daily answered by the Cairo & St. Louis Narrow Gauge Road, 90 miles of which have been in operation for some time. Their passenger trains run this distance in 4 hours 50 min., and make 16 stops. Their schedule time is over 18.6 miles per hour over maximum grades of 94 ft. to the mile, and their regular train is four cars, weighing in the aggregate, with passengers, 52 tons. This is about the average rate of mail trains on wide-gauge roads with much easier grades. The engines were built at the Light Locomotive Works of Porter, Bell & Co., Pittsburg, Pa., and have 10x16 in. cylinders and

44-in. drivers. On a special trial one of the three engines hauled its train 9 miles in 10 min., or at the rate of 54 miles per hour. Several prominent Chicago railway officials were on the train, two of them riding with the engineer when this "spurt" was made. They pronounced the motion quite as easy as on any broad-gauge road.—*Chicago Railway Review.*

ENGINEERING STRUCTURES.

The Largest Tunnels of the World.—The completion of the Hoosac tunnel and the rapid progress of the Sutro, have caused the miners, both in the East and in the West of America, to look with interest upon what has been and is projected in connection with tunnel driving. It is in Germany that the great tunnels have been constructed, and these have been made exclusively for mining. There is the great tunnel at Freiberg, 24 miles long; the Ernst-August and the Georg at Clausthal, 13½ and 10¾ miles respectively; the Joseph II. at Schemnitz, 9¼ miles; the Rothschonberg at Freiberg, 8 miles; the Mont Cenis, 7½ miles, which about completes the European list. In the United States we have the Hoosac, in Massachusetts, 5 miles long, the completion of which has lately been noticed; the Sutro, in Nevada, for opening up the celebrated Comstock lode. This tunnel, although only 4 miles long, will, with its ramifications to the various mines of the district, prove one of the most important in America. The Sierra Madre tunnel at Black Hawk, commenced during the present year, and which will be 12 miles long, as well as the San Carlos and Union Pacific tunnels, which are under 2½ miles. The Ernst-August tunnel was driven at the rate of a mile per annum, and it will be interesting to notice how long it will take the Americans, with all the approved appliances at present at command, to complete the nearly similar Sierra Madre tunnel.

The Detroit Bridge.—The report of the commissioners appointed by the Secretary of War to inquire into the feasibility of bridging the Detroit River has been laid before Congress. The commissioners have given a hearing to all parties interested and have collected statistics bearing on the question. They are inclined to think the water traffic much more important than the railroad traffic which crosses the river, and believe that a tunnel is the only unobjectionable method of overcoming the obstruction to railroad traffic. This tunnel they believe to be practicable. No bridge giving passage to vessels by draws alone, with any draw-span now possible, can be built without serious obstruction to navigation. A bridge giving a clear headway of 150 ft. and clear spans of 400 ft. would not seriously obstruct navigation, but would be very expensive and the approaches would be long, and very inconvenient to construct. A third plan considered was a bridge for winter use only, resting on pontoons in the centre of the river and piers at the sides, which could be removed so as to leave a clear opening of 700 ft. during the season of navigation. This, the Commission believes, could be built without serious hinderance to navigation and at a reasonable cost, but it would only be of use some five months of the year.

ORDNANCE AND NAVAL.

A Destructive Engine of War.—The recent trial of the Taylor battery gun, upon which the Colt Company, of Hartford, has for some months past been engaged, shows it to be the most formidable weapon of war that has yet been invented. Its barrels are twenty-four in number, and are arranged in two concentric circles. They are also regulated so as to radiate their fire, covering a horizontal line of 22 ft. at a distance of 500 yards. The gun fires with great rapidity, by fusilade or by volley, at the pleasure of the operator, while the cartridges are fed into the barrel from suitable charging cases, which are introduced into the interior of the breech cylinders. The results at the late trial were astonishing. In firing a single barrel at a distance of 500 yards, bullets were repeatedly sent into an 8-in. bull's-eye. In firing the fusilade, the 24 balls were distributed on a horizontal surface 22 ft. long at a distance of a foot apart; and firing by the battery the same results were accomplished. The rapidity of the fire was remarkable, being at the rate of 700 balls per minute. The terrible effectiveness of this weapon in battle, and the utter powerlessness of charging columns in the face of a fire, can be seen by the fact that every second sweeps over 20 ft. in length, and mows down men at the rate of a regiment a minute. The inventor of this remarkable weapon is Colonel James P. Taylor, of Knoxville, Tenn. His invention was conceived in 1870, and patented in July, 1871, and it has since been improved until its present extreme simplicity and effectiveness have been reached. The manufacture of the gun is to be rapidly pushed, and active measures taken for its introduction among foreign governments.—*Iron World.*

Iron Steamers for South America.—Two iron steamers have been completed at Messrs. Hartupee & Co.'s foundry in Pittsburg for service in South American waters. The vessels were built for the Rio Janeiro Steamship Navigation Company, and will be shipped in sections and put together on their arrival at Buenos Ayres. The smaller boat, with her machinery complete, only weighs 13,000 lbs., and is 90 ft. long, while the larger is 120 ft. in length, 26 ft. beam, and 4½ ft. hold. Messrs. Hartupee & Co. will probably soon receive another and a larger contract from the company, a correspondence relative thereto having taken place. These vessels after being put together are taken apart and packed in boxes, every piece being numbered. No less than 1,200 boxes are required.

The Committee on Explosives at the Royal Arsenal, Woolwich, are about to make some experiments with an 18-ton gun, for the purpose of testing the advantages to be gained by various lengths of bore. The gun prepared for these experiments has a rather eventful history. It was first of all fired as a 10-in. gun, re-rifled, and drilled through and through in various parts for the insertion of pressure gauges to ascertain the force of the explosion, and the gun in this state sustained some very heavy strains. It was afterwards rifled, and again underwent some extraordinary pressures, and it was subsequently bored up to 11 in., firing a number of rounds with heavy charges, until at length the tube cracked while firing 1,200 lbs. shot with 85 lbs. of powder. A new tube has since been put in, and a considerable piece added to the muzzle, so that the gun is at the present a little over 20 ft. long, with a bore of 11 in. still. The most advantageous length for land service guns will, no doubt, be ascertained by experiments with this piece of ordnance. Naval guns are of necessity short. The advantage of length of bore is that slower burning, and consequently less dangerous powder can be used, as the guns have a longer space in which to act upon the shot, which thus acquires its velocity at less expense to the gun. The gun above described has been fully prepared at the Royal Gun Factories in the Royal Arsenal, Woolwich, for these experiments.

BOOK NOTICES.

A Practical Manual of Chemical Analysis and Assaying, as applied to the Manufacture of Iron from its Ores, and to Cast Iron, Wrought Iron and Steel, as Found in Commerce. By L. L. De Koninck, Dr. Sc., and E. Dietz, Engineers. Edited with notes by Robert Mallet, F. R. S. London: Chapman and Hall. For sale by D. Van Nostrand.

If it is true that no complicated manufacture of modern times can be successfully carried on and improved without the continual aid of science, then we shall be prepared to expect that in localities in which any such manufacture is extensively and successfully followed, the sciences related to it will be thoroughly investigated in theory and reduced to form as practical arts. This is particularly the case with the manufacture of iron and steel; and no one who has personally observed the perfection and the proportions of this business in Belgium, will be surprised to find that it is accompanied in that country with a valuable technical literature. The authors of the manual before us, being both skilful and learned in the metallurgy of iron, have undertaken to present, in a concise form, the information most frequently required by chemists in iron works, for whom this book is specially intended. But, as the editor justly remarks, it is a work, from the careful study of which, accompanied by the self-instruction derivable from a repetitive course of the operations described, any tolerably intelligent man, with some preliminary knowledge of organic chemistry and manipulation, might become a practical iron assayer. It is, therefore, particularly well adapted to be useful to American iron masters, many of whom already possess, and all of whom may easily obtain, the prerequisite general acquaintance with chemical principles and processes.

The plan of this manual will appear from a brief recital of its contents. The first part contains a description of the reagents to be employed, and the experiments necessary in order to ascertain their degree of purity; in the second part are given some practical suggestions relative to the apparatus employed in the laboratories attached to ironworks; the third part treats of volumetric assaying; the fourth is devoted to the analysis of iron ores, slags, and scoriæ, by the wet method; the fifth part treats of the assay of the same ores by the dry or docimastic method proper; the sixth gives the methods of analysis of malleable iron, cast iron, and steel; and the examination of fuels forms the seventh and last part. Since zinc and lead ores are occasionally found more or less in company with ores of iron, so as to complicate the analysis of the latter, the treatise is completed by a brief indication of methods generally used in analyzing them.

We have examined with interest the different sections of the book, with the view of ascertaining how clearly, and with how much detail, the processes involved are described, and to what extent the latest improvements in laboratory practice are included. In both respects we are able to commend the book heartily. Yet, excellent as was the treatment bestowed upon it by its authors, the admirable notes added by Mr. Mallet have, in our opinion, greatly augmented its practical value. They refer mainly to topics connected with actual practice in the laboratory, and contain a great number of useful suggestions, such as an accomplished teacher might drop for the benefit of his pupils in the familiarity of daily association.

The employment, in this manual, of modern chemical formulæ and atomic weights may prove at first somewhat inconvenient to those who have been brought up under the old-fashioned nomenclature; but, after all, there is no doubt that the new theories and arrangements of symbols will ultimately replace the old, and whoever intends to keep pace with the progress of technical literature must make up his mind, whether he likes it or not, to master its language. From this point of view, it is a great advantage to possess a text-book, by the aid of which modern treatises can be interpreted.

We notice that in the account of the colorimetric method of determing combined carbon in cast iron or steel, the very convenient apparatus devised by Mr. Britton is not described. This apparatus is specially adapted for use in large establishments, when frequent assays are required.

At the end of the book are several tables, giving the chemical equivalents, stoichiometric coefficients, and comparative weights and measures. The latter table enables a student to turn metric weights into British grains, but unfortunately does not facilitate the reverse calculation.—*Engineering and Mining Journal.*

Naval Architecture: an Elementary Treatise on Laying-off Wood and Iron Ships. By J. S. P. Thearle. London and Glasgow: W. Collins, Sons, & Co.

This little book, which seems to be one of a series of elementary science manuals in course of publication by the Messrs. Collins, had its origin in the desire of its author to supply a want he himself felt when a student. The book itself is a small 8vo, but it is accompanied by what is called vol. ii., a quarto containing the plates illustrative of the text. Mr. Thearle, who is in the department of the Comptroller of the Navy, is thoroughly competent to write a work of this kind, and we do not doubt that it will be of considerable importance to the student of naval architecture, containing, as it does, an explanation of nearly all the problems of common occurrence on the floor of the mould-loft. The technical terms used in this art of "laying-off" vary to such an extent in the different shipbuilding yards of the country, that

Mr. Thearle wisely adopts many terms used in descriptive geometry, thus obtaining a uniform nomenclature which will not be liable to be misconstrued by students in various parts of the kingdom. The text is divided into two parts, treating respectively of wood and iron vessels, and these again into chapters. After a brief introduction and an explanation of terms, Mr. Thearle plunges at once into the mysteries of the mould-loft and into technical details, which are, of course, of interest only to the student of the subject. About 120 pp. of text, and nearly fifty lithographic diagrams, enable the author to convey a thoroughly practical idea of the art.

OUTLINES OF GEOMETRY, OR THE MOTION OF A POINT. An Introduction and Companion to Euclid's Elements. By W. MARSHAM ADAMS, B. A. Third revised edition. London: Mead & Co.

Instead of seeking a substitute for a first book which has held its own as an introduction to geometry for some 3,000 years, a search apparently futile, Mr. Adams proposes in this work to provide the student, not with a substitute, but with an introduction to prepare him for the elements rather than to adapt the elements to him, and this by "presenting each geometrical conception in the concrete before it is presented in the abstract, so that the image in the mind precedes the definition." Evidently well acquainted with the *idola* which occupy the mind of the geometrical tyro, Mr. Adams, with much tact, dislodges these, substituting the accurate conceptions of exact science; in fact, communicates the same kind of preliminary information which might be given orally by a judicious teacher; and for this reason his little work must be invaluable as a help to those applying themselves to geometry without the aid of a master, or as a hand-book to inexperienced teachers of youth. Two sheets of diagrams, in some of which color is utilized, amply illustrate the letter-press.

HYDRAULICS OF GREAT RIVERS. THE PARANA, THE URUGUAY, AND THE LA PLATA ESTUARY. By J. J. REVY. For sale by D. Van Nostrand. Price $17.00, cloth.

The author of this work was appointed, three years ago, by the Argentine Republic, to survey their great rivers, and, as the magnitude of the subjects of the survey was so much in advance of the sources of the data hitherto employed in hydraulics, he took especial pains to insure a degree of accuracy not usually required for ordinary purposes. Acting on this determination, he made his observations, an analysis of which, we now find, gives results at variance with some of the principles accepted by hydraulic engineers. Mr. Révy has contented himself with giving an account of his survey and of its results; he does not attack the theories of others, nor state one of his own. The book is illustrated with excellent diagrams, and contains, amongst other things, a description with illustrations of a new current meter. The subject is one of special interest to hydraulic engineers and to Boards of Works, and dealing, as it does, with the preservation of rivers as channels of communication, it is of imperial importance. Mr. Révy writes in an agreeable style for such a subject, and many of his pages contain information upon the geology of the districts, while here and there is an account of an adventure—the rivers being at the time, it will be remembered, the "seat of war."

TATE'S SURCHARGED AND DIFFERENT FORMS OF RETAINING WALLS, AND TURNBULL'S TREATISE ON THE COMPOUND ENGINE.

"The above named works form Nos. 7 and 8 of Van Nostrand's Science Series, several times mentioned in our columns. The value of the treatise on retaining walls is sufficiently guaranteed by the name of the author, who is well known as a very able engineer. The discussion on the subject involves the use of mathematics to such a degree that it will not be comprehensible, except to such as have been mathematically trained. The tables derived from the discussion are, however, of great value for reference. They are five in number. The first gives the thickness of vertical retaining walls, to sustain the pressure of earth, sand, etc., level with its top for different heights of walls. The second table gives the double moments of the pressure of the weight of embankments of earth, sand, etc., level with the top of wall for different heights. The fourth table gives the thickness of vertical retaining walls to sustain the pressure of a surcharged embankment of earth, sand, etc. The fifth table gives the double moments of the pressure of the weight of surcharged embankments of earth, sand, etc. In the treatise on the compound steam engine, the use of mathematics is so far avoided that almost any one familiar with the structure of steam engines may read it understandingly. Theoretical and indicator diagrams are given, which clearly illustrate the subject."—*New York Artisan.*

INTRODUCTION TO THE STUDY OF ORGANIC CHEMISTRY: THE CHEMISTRY OF CARBON AND ITS COMPOUNDS. By HENRY E. ARMSTRONG, Ph. D., F. C. S., Professor of Chemistry in the London Institution. London: Longmans, Green, and Co.

The greatly increased facilities which a sound knowledge of organic chemistry affords for the successful carrying on of many branches of our national industries is now very generally recognized, yet the difficulties usually attending the earlier studies of the subject suffice to prevent a large number of even diligent students from acquiring anything approaching a satisfactory acqaintance with it; henceforth, however, these difficulties will be materially lessened, since from Prof. Armstrong's admirable little volume, just issued as one of the Messrs. Longman's Text Books of Science, so complete an outline of the subject may readily to obtained as will be valuable of itself, and extremely useful for facilitating the profitable reading of the most complete works bearing upon the technology of any particular manufacture. The matter is treated in a thoroughly systematic and scientific manner, yet the style is sufficiently popular for any student of ordinary intelligence to derive advantage from it; he will learn the methods employed in ascertaining the composition of carbon compounds, and of representing them by empirical formulæ, and by formulæ which not only express their composition, but to some extent their nature also. He then proceeds to the consideration of the action of reagents on carbon compounds, and of the compounds of carbon with oxygen, sulphur, and nitrogen respectively; the remaining families of carbon compounds are then considered in the order of their relation to the hydrocarbons.

The volume is in every respect adapted to the wants of the practical man; it will afford him all the information likely to be useful to him in carrying on his business to the greatest advantage, without troubling him with more theoretical details than are absolutely necessary to enable him thoroughly to comprehend the facts placed before him. In producing such a book Prof Armstrong shows not only that he is himself a master of the subject, but that he possesses great facility for imparting that knowledge to others.

AN ELEMENTARY TREATISE ON STEAM. By JOHN PERRY, B. E. London. For sale by D. Van Nostrand. Price $1.50, cloth.

This little 16mo volume of 400 pages contains more correct information on the subject of Steam Motors than we have found before within so small a space. It is moreover exceedingly well adapted to the use of students, affording numerous well selected problems for practice.

To read it profitably the student must be familiar with simple algebraic equations, the first principles of trigonometry, and the leading facts of elementary physics.

The author has divided the whole work into four parts or books treating respectively of Heat—Steam Engines and Boilers—Locomotives, and Marine Engines. The illustrations, about eighty in number, are distributed through the text.

BUILDING CONSTRUCTION; showing the Employment of Brick, Stone and Slate in the Practical Construction of Buildings. By R. SCOTT BURN. New York: G. P. Putnam's Sons.

This is a recent addition to Putnam's Elementary Science Series.

It is exceedingly rudimentary in plan, but little if anything more being attempted by the author than briefly defining and illustrating the technical terms employed in building.

The book doubtless affords excellent suggestions to the teachers of object lessons in our primary schools. The student who desires to learn something of building is referred to the more advanced books.

Vol. 2d. Plates to the above; giving in a neat form examples on a more liberal seale than those interspersed in the text.

BUILDING CONSTRUCTION, showing the Employment of Timber, Lead and Iron Work in Construction. By R. SCOTT BURN. New York: G. P. Putnam's Sons.

Vol. 1.—Text.

Vol. 2.—Plates.

The chapters into which this brief treatise is divided treat successively of:

Chap. 1st. Drawing—Drawing Instruments—Drawing Scales—Plans, Elevations, and Sections.

Chap. 2d. Timber construction as exemplified in the framing of floors, partitions, and roofs.

Chap. 3d. Timber construction as exemplified in doors, windows, and internal fittings of houses.

Chap. 4th. Work in Lead and Iron.

As in the preceding there are many wood-cuts distributed through the text for its illustration.

The second volume contains twenty neatly executed plates, which seem judiciously selected with reference to affording a good variety of examples.

FUEL. By WM. SIEMENS, D. C. L., F. R. S. To which is appended. THE VALUE OF ARTIFICIAL FUELS AS COMPARED WITH COAL. By JOHN WORMALD, C. E. New York: D. Van Nostrand. Price 50 cts., boards.

This is the latest issue of Van Nostrand's Science Series. Both essays have appeared in the pages of this magazine. They are different from each other inasmuch as the former is a thorough exposition of the laws of combustion and the necessary deductions to be carefully remembered in their application; while the other is of a thoroughly practical kind, and discusses recent experiences with some of the expedients devised to save the cost attendant upon burning coal only.

TABLEAUX COMPARATIFS DES MESURES, POIDS ET MONAIES. Par HERCULE CAVALLI. Paris: Libraire Administrative de Paul Dupont. For sale by D. Van Nostrand.

This collection of tables seems to be altogether indispensable to the reader of history as well as to the student of art or science.

The weights, measures and coins of all countries and all times are compared with the English and French standards.

We have rarely seen a work containing tables only which was designed to satisfy a want of so many classes of readers.

ETUDES SUR LES CONSTRUCTIONS A LA MER. Par M. BONNICEAU. Paris: Lacroix. For sale by Van Nostrand. Price $7.20, cloth.

This compact little work affords an insight into the engineering methods employed in the improvement of harbors, in many parts of the world, and in both modern and ancient times.

Wharves, Docks, Jetties, Bridges and Lighthouses are all treated in turn and all abundantly illustrated in the accompanying volume of plates.

AN ELEMENTARY TREATISE ON QUATERNIONS. By P. G. TAIT, M. A. Second edition. Oxford: Clarendon Press. For Sale by D. Van Nostrand.

Mathematical students or students of applied science who hope to continue their labor with profit for another decade, must evidently read up on Quaternions.

The signs are abundant that this department of mathematics is rapidly being employed effectively in investigations of physical laws.

The first edition of this elegant work was widely sold in this country; a fact which the author gratefully acknowledges in the preface to the present edition.

The author's renown is such that we need not attest the thoroughness or clearness of the treatise.

DICTIONARY OF ELEVATIONS AND CLIMATIC REGISTER OF THE UNITED STATES. By J. M. TONER, M. D. New York: D. Van Nostrand. Price $3.50 cloth.

This work contains in addition to elevations, the latitude, mean annual temperature, and the total annual rain-fall of all the cities, towns and localities in the United States, concerning which the requisite data have been obtainable. The orographic and other physical peculiarities of North America, and more briefly of the world, have also been noted with the care and industry for which the author is distinguished, and altogether the work supplies an amount and kind of information that makes it unique in the field occupied. The work, he says, has been undertaken chiefly for the purpose of placing within reach of the medical profession a record that may enable and induce professional men in different localities to observe, record, and contrast the influence of elevation, if it has any, on health and disease. Hitherto latitude and longitude have been the chief and almost the only conditions modifying climate, that have been taken into account in considering the influences of localities on health; but the observations of physicians and travellers present facts suggesting that altitude to some extent controls the type of diseases. Of course it is necessary for the observer to keep in view the influences not only of latitude and longitude, but also of a dry or a humid atmosphere, and of a high or a low barometer. The Dictionary points out convenient modes of taking observations by those feeling an interest in the subject. Heights of localities may be determined approximately with the aid of a barometer, as the mercury falls in it about 1 in. for every 940 ft. of elevation above the level of the sea; or by boiling water, which at sea level boils at 212 deg., but owing to the lessened weight of atmosphere in ascending, boils at the rate of 1 deg. less for every 450 ft. of perpendicular ascent. The thermometer, too, registers in almost any locality 1 deg. lower temperature for about 300 ft. of perpendicular height above the level of the sea. These conditions or laws of the ocean of atmosphere in which we live, and which has a depth estimated at 45 miles, and weight of 15 lbs. to the sq. in., are nearly constant, and with the well-known purity of the free circulating air and the great abundance of electricity and ozone, which constantly pervades elevated localities, are elements too potent not to exercise an important influence on man's well being. All the data obtainable, points to the fact that a residence in a moderately elevated region, either in the tropical or temperate zone, anywhere between a few hundred feet above the level of the sea, and a line that marks Alpine vegetation, is healthier that the tide-water lands. It is in this intermediate strata of climatic and barometric influence that the human race attains its noblest physical development. The most productive States of our Union, with the largest population and with the greatest aggregate wealth, are to be found among those having an average elevation above the sea of from 400 to 1,000 ft. The pursuits of commerce have, however, caused most of our large cities to be placed on low ground, near navigable waters. The table of 311 towns in this Dictionary shows that the majority of the denizens of our large American cities are living at an elevation of but a few hundred feet above tide water; and that there are eighty cities situated at an elevation of less than 100 ft. above sea level, with a combined population of 4,868,107. It does not appear that the site of a single city in the United States has been selected because of the special salubrity of the locality. In a hygienic sense it is to be regretted that the larger commercial cities do not occupy more elevated sites. There is a noticeable peculiarity in the location of our American cities, at or near the mouth of rivers emptying into the Atlantic ocean, in the fact that they are all situated on the left bank; and, further, there is scarcely an exception to the fact that to the south of all these cities there are large marshy flats, over which the prevailing winds blow, and carry the miasm directly across the cities.—*Washington Star.*

MISCELLANEOUS.

Peter Cooper.—This venerable philanthropist has just entered upon the 84th year of his useful and honorable life, and in recognition of his exalted character and many public services, a birthday reception was given him on the 12th inst. by a number of our most distinguished citizens, all of whom joined in expressing their esteem for him. We quote the following eloquent passages from his remarks in reply to the address of congratulation delivered on that occasion:

"Measured by the achievements of the years I have seen, I am one of the oldest men who have ever lived; but I do not feel old, and I propose to give the receipt by which I have preserved my youth. I have always given a friendly welcome to new ideas, and I have endeavored not to feel too old to learn—and, thus, though I stand here with the snows of so many winters upon my head, my faith in human nature, my belief in the progress of man to a better social condition, and especially my trust in the ability of men to establish and maintain self-government, are as fresh and as young as when I began to travel the path of life. While I have always recognized that the object of business is to make money in an honorable manner, I have endeavored to remember that the object of life is to do good. Hence I have been ready to engage in all new enterprises, and, without incurring debt, to risk the means which I had acquired, in their promotion, provided they seemed to me calculated to advance the general good. This will account for my early attempt to perfect the steam engine, for my early attempt to construct the first American locomotive, for my connection with the telegraph in a course of efforts to unite our country with the European world, and for my recent efforts to solve the problem of economical steam navigation on the canals; to all of which you have so kindly referred. It happens to but few men to change the current of human progress, as it did to Watt, to Fulton, to Stephenson, and to Morse; but most men may be ready to welcome laborers to a new field of usefulness, and to clear the road for their progress.

"This I have tried to do, as well in the perfecting and execution of their ideas, as in making such provisions as my means have permitted for the proper education of the young mechanics and citizens of my native city; in order to fit them for the reception of new ideas, social, mechanical, and scientific; hoping thus to economize and expand the intellectual as well as the physical forces and provide a larger fund for distribution among the various classes which necessarily make up the total of society.

"I feel that nature has provided bountifully for the wants of all men, and that we need only knowledge, scientific, political, and religious, and self-control, in order to eradicate the evils under which society has suffered in all ages. Let me say, then, in conclusion, that my experience of life has not dimmed my hopes for humanity; that my sun is not setting in clouds and darkness; but is going down cheerfully in a clear firmament lighted up by the glory of God, who should always be venerated and loved as the infinite source and foundation of all light—life—power—wisdom and goodness."

Notes on Magnetism.—M. Gaugain.—A singular fact is stated. If a bar of iron is magnetized as strongly as is possible with a current of determinate intensity, one may increase its magnetization by employing currents with the same direction, but of less intensity. Thus having magnetized a horse-shoe bar to the maximum obtainable with a current of intensity 39,594, the current of detachment obtained under the influence of the constant magnetism was 45. Then M. Gaugain re-commenced the magnetization, using, successively, currents with the intensities 16060, 12069, 6993, and 5161; and the values of the corresponding currents of detachment were 49.8, 52.9, 56.5, and 57.9. He then tried again the current used first, and the current of detachment fell to 45. Thus, the magnetization developed by a weak current is destroyed by a more energetic current in the same direction. But this curious fact and that mentioned in paragraph 52 (see "Telegraphic Journal," page 21), depend on the mode of detaching the armature. This, in the cases described, was by a sudden movement in a direction perpendicular to the polar faces; if it is detached by making it glide parallel to these faces, the results are different. Using the process of magnetization described in paragraph 52, the maximum value of constant magnetism is greater than in the case where the armature is detached by a sudden movement; and in the case just described, successive weaker currents did not increase the magnetization. M. Gaugain thinks it certain that the detachment of the armature always weakens the magnetism, and that it is by causing a shaking (*ebranlement*) among the iron molecules, which diminishes the coercitive force. He thus explains the phenomena described in paragraph 52: According to Ampère's views, magnetization consists in a certain orientation of molecules, or of currents which circulate about them; and, since the persistent magnetization of iron is very different from the magnetization it acquires from an inducing current, we must suppose that the molecules which remain directed (*orientées*) after the interruption of the inducing current and the detachment of the armature, are, from their nature and position, endowed with a greater coercitive force than the other molecules. Now when one performs, for the second time, the series of operations in paragraph 52, it is evident that the molecules preserving their orientation after detachments of the armature of the first series, will not be deranged by the renewal of the inducing current; and they will, naturally, be more apt than others to resist the shaking caused by new detachments of the armature. On the other hand, among the molecules on which the current impresses a movement of rotation, there will be new ones which will possess this coercitive force necessary for the orientation to become persistent. We can thus conceive that the number of molecules directed in a permanent manner may be greater after the second series of operations than after the first, although the detachment of the armature has always the effect of diminishing the permanent magnetism; each new series of operations has the effect of establishing a sort of selection among the molecules, and bringing to magnetic orientation those which possess the greatest coercitive force. The magnetization ceases to increase when all the molecules gifted with this superior coercitive force have received the magnetic orientation. Next, as to the effects stated in the beginning of this note. When the current 39594 has acted, and the magnetization has been raised to its maximum, we must suppose that there is no longer, in the annular space influenced by this current, any molecule to direct, among those possessing coercitive force sufficient to resist the detachment of the armature. But it is natural to suppose that the molecular shaking, which results from this detachment, is more violent the stronger the armature is held, the more intense the inducing current; and we may conceive that the molecules which have not a sufficient coercitive force to resist the detachment of the armature which followed the passage of the current 39594 can nevertheless retain their orientation when the armature is detached after passage of a weaker current. This being allowed, we can readily understand how a weaker current may reinforce the magnetization developed by a stronger current; the molecules which the former brings to magnetic orientation will be equally brought to it by the latter; but they preserve their orientation when the weaker of the two currents is employed, and do not preserve it with the stronger current; because the shaking which results from detachment of the armature is less violent in the first case than in the second. The increase of magnetization obtained when the armature is detached by sliding along, instead of sudden detachment, is explained by the consideration that the molecular shaking must be less violent in the former case than in the latter.

A Remarkable Pumping Engine.—The last number of the "Journal of the Franklin Institute" contains the report of the trial of the new Worthington duplex pumping engine, at Phœnixville, Pa. This is a compound duplex of a new type, having but one high-pressure and one low-pressure cylinder, instead of two of each kind. Of the two pumps, one is worked by a high-pressure cylinder, exhausting into a tank, and the other by a low-pressure cylinder, receiving steam from the tank. There is no expansion in either cylinder. The high-pressure pump-plunger is 12 in., with a piston-rod 2½ in. in diameter; the low-pressure plunger is 14 in., with a piston-rod 3 in. in diameter; the stroke is 2 ft., and the capacity 54.24 galls. per revolution of both pumps—the term revolution being employed to signify a complete double stroke, or what would require a revolution if the engine had a crank. It will be seen that the dimensions given are so small as not to be ordinarily associated in practice with the highest degree of economy. The contract made with Mr. Worthington demanded a capacity of 1,000,000 galls., lifted 182.79 ft. in 24 hours, and a duty of 45,000,000 foot-pounds per 100 lbs. of coal. On the trial the pumps actually raised in six hours an amount of water representing 1,626,436 gallons in

24 hours, and achieved the duty of 68,620,360 foot-pounds, without any allowance for friction in the pipes. The committee adds in its report that Mr. Worthington is fairly entitled to add 2 ft. to the actual height pumped, which will give him an actual duty of 70,422,306 foot-pounds. This extraordinary performance will attract much attention from engineers. We need only say, with regard to it, that the trial-report shows no evidences of forcing the figures to obtain this result, and that the little pump which thus challenges the Cornish engine itself, is compact and cheap, as well as efficient.

JARRE'S POWER PUMP.—A year or two since there was some talk of the hydro-pneumatic pump of M. Jarre, for the transmission of power to a considerable distance; M. Haton has now made a report upon it to the Société d 'Encouragement of Paris.

The problem of transmitting power over long distances full of obstacles is undoubtedly not an easy one, and M. Jarre avails himself of compressed air for the purpose, and acts directly on the water without the aid of a piston. The pressure in the air conduit being subject to little variation, and resulting from the action of the force-pump, which is placed at a long distance from the source to be drawn from, a special arrangement was necessary to work the valves of injection and emission.

M. Jarre has adopted an intermittent fountain. An oscillating beam alternately opens and closes the way through which the compressed air finds its way to the surface of the water to be raised, according to the variations of weight in two movable parts of the apparatus, when in air and when immersed in water, that is to say, when the level of the water rises or falls. The action of the compressed air thus follows closely the movement of the water, and the pump continues its action so long as the pressure of the air is sufficient.

Several pumps of this kind have worked with success for two years at the Ornans Works, of which M. Jarre is directing engineer. It is admitted that there is a disadvantage in causing the air to act directly on the water, because the effective pressure is thus limited to the fixed pressure of the ascending column of the liquid, and by any loss in the conduits; but this objection is compensated by the special advantages of the pump in certain cases. Thus, one of them is placed at the distance of nearly 500 feet from the motor, and the compressed air reaches it through a tube only four-fifths of an inch in diameter, and having twenty-eight heads at right angles. The water raised, which amounts to eighteen gallons per minute, is conducted through a pipe of 1⅝ inches in diameter, with nine right angle bends, and two stopcocks.

INCRUSTATION IN BOILERS.—Messieurs Champion and Pellet have made a communication to the Society of Civil Engineers of Paris on the important subject of incrustation in boilers.

The authors say the most certain mode of avoiding deposits and incrustations is to separate the calcareous salts from the water before its introduction in the boiler; and incrustation they declare is caused principally by the water containing both sulphate and bicarbonate of lime. In this case barytes, a or mixture of soda and lime, may be used with success. The authors occupy themselves especially with the deposits formed by the decomposition of the bicarbonate of lime under the influence of heat, and which causes such freqent accidents. The carbonate, acted upon by an excess of carbonic acid, takes with it, in precipitating, small quantities of greasy matter contained in the water, and the pulverulent deposit thus formed prevents the contact of the water with the sides of the boiler.

The mode proposed for preventing this, lately adopted on the Northern Railway of France, consists in the addition of milk of lime corresponding in quantity with the excess of carbonic acid. This system, however, which answered perfectly at some sugar works at the end of one season, was found inefficient in the following year; and MM. Champion and Pellet instituted further experiments, and state that when lime-water is introduced into water containing a certain amount of calcareous bi-carbonate, so as to saturate the excess of carbonic and, a flocculent precipitate of carbonate of lime is quickly formed; and if the water is left quiet for a few hours, and filtered, it is then exempt from lime; if, on the contrary, the carbonate is less in quantity, no precipitation is formed, even by agitation after many hours. In this latter case, MM. Champion and Pellet have found that the carbonate is in a condition of supersaturation, and possesses a considerable amount of solubility. This property alone, however, is not considered sufficient to account for the failure in question.

Comparing results, it appears likely that the non-precipitable carbonate might be removed by the formation in the water of an abundant precipitate of carbonate of lime, obtained by means of a soluble salt of lime, and such proved to be the case. It was found, morover, that the addition of certain pulverulent substances, such as silica, lime, or natural sand in fine powder, produced a like effect. It appears, therefore, that the presence of a precipitate, even of a foreign nature, causes a sort of disassociation between the water and the carbonate of lime, and the precipitation of the latter. The failure already referred to must have arisen from a variation in amount of carbonic acid in the water, and consequently in the proportion of carbonate of lime dissolved; it is evident, therefore, that it is necessary to ascertain the amount of the carbonate of lime and the excess of carbonic acid in the water. In effect this excess furnishes, in contact with the lime, a new quantity of carbonate, which, added to the first, may cause precipitation.

From the above experiments and facts, MM. Champion and Pellet deduce the following general method of treating water, in which the proportion of lime is not sufficient to cause precipitation. It is sufficient, they say, to add a few thousandth parts of pulverized limestone to water already saturated by the proportion of lime corresponding with the excess of carbonic acid, but it is preferable to use carbonate of soda instead of lime, an excess of which would give rise to accidents, which we desire to avoid. Even oxalate of ammonia, active test as it is, will not show a trace of lime in water thus treated. After some hours' repose, the greater part of the carbonate is deposited, and what remains in suspension may be removed by filtration.

VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

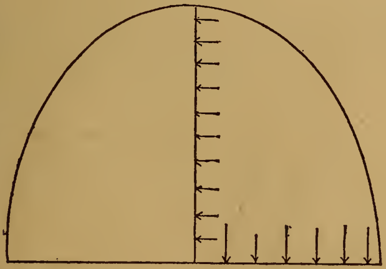
No. LXV.—MAY, 1874.—Vol. X.

THEORY OF ARCHES.

(*Continued from page* 296.)

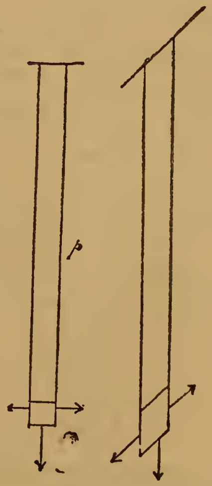
4. There is no case in ordinary practice where the pressures upon an arch are strictly identical with those on an elliptical cord, for in this case, the pressure must be constant in intensity along both the horizontal and vertical projections of the arch, but the intensity along the *horizontal* must differ from that along the vertical in a constant ratio (Fig. 41). But as Prof. Rankine says, the curve of equilibrium for the arch of a tunnel through earth, when the depth below the surface is great compared with the rise of the arch itself, approximates to an ellipse.

Fig. 41.



The pressures in a mass of earth are intermediate in character between those existing in a solid and those in a liquid mass. Thus a little cube of earth (Fig. 42) under the weight of the superincumbent column of earth p, presses downward with a force equal to its own weight and that of the column above. It also presses out horizontally with a force *less than this downward force*, but always *bearing a constant ratio to it.* If the little cube were *solid* it would have *no* horizontal push; if *liquid*, that horizontal push would equal its pressure downward. If the upper surface of the earth is inclined, the outward push which always remains parallel to it becomes inclined too, and is then "conjugate" to the vertical.

Fig. 42.

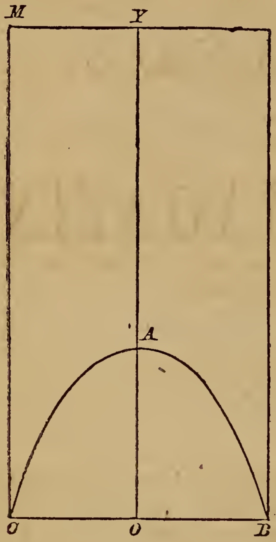


If M Y (Fig. 43) is the surface of the earth, when Y A is great compared with A O, then Y A and M C differ so slightly that we may assume them to be equal. We then have on the arch a uniform vertical load whose intensity =

p_v = (Y A) × weight of a unit of the earth $= wy_0$;

and a horizontal load whose uniform intensity p_x is equal to the vertical intensity (p_y) multiplied by a constant. Let

Fig. 43.



$$\frac{p_x}{p_y} = c^2 \text{ (a constant).}$$

Then

$$p_x = c^2 w y_0 \text{ and } c = \sqrt{\frac{p_x}{p_y}}.$$

From the discussion of Case V. we see that c must be the ratio of the axes of the ellipse to which the pressures are respectively parallel. Hence if the arch be a semi-ellipse and O B be given, we have

$$\frac{\text{O B}}{\text{O A}} = c \therefore \text{O A} = \frac{\text{O B}}{c}.$$

From these data draw the curve of the soffit.

The thrust along the soffit at A

$$= \text{H} = p_y \rho_0 = w y_0 \rho_0.$$

At C or B it is $\text{V} = p_x \rho_1$.

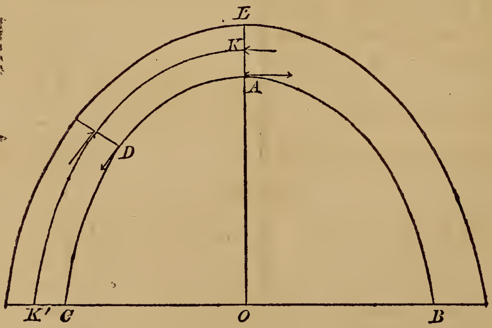
At other points it may be gotten from eq. (27) Case V.

We can determine the curve of pressures by a method similar to that used in the last case. Here, however, the curve K K′ will not be parallel to C A, since the thrusts along C A are not constant, but increase from A to C. Assume A K (Fig. 44) $= \frac{2}{3}$ A L, then the arch must be so proportioned that K K′ shall fall within the middle third.

If the arch C A B is not to be a *semi*-ellipse (as above assumed) but only a *segment* of one, a few trials will enable us to get the ellipse from the data already given.

The strictly true curve of equilibrium required by earth pressure is the Geostatic arch.

Fig. 44.



5. An arch built with the curve discussed in *Case VI.*, is known as the Hydrostatic arch, from the fact that the loading there described is similar to the pressure of water upon a *vertical* arch.

For if M Y (Fig. 45) be the surface of the water, then its pressure on C A B is normal and proportioned at each point to the depth below M Y. This pressure, as has been shown, may be resolved into a vertical and horizontal pressure at each point, this vertical and horizontal pressure being equal in *intensity* to each other at every point, and also to the normal pressure of which they are the components.

The above form of arch may be applied in two cases.

(1) To bear the pressure of water or other liquid. Thus in the case of a river tunnel (such as those at Chicago) where the top of

the tunnel is practically on a level with the bottom of the river, we might use the hydrostatic arch.

The equation of the curve is

$$y\rho = y_0 \rho_0 .$$

The vertical load on the half-arch A B

$$= \int_{x_1}^{0} p\,dx = \mathrm{V} = w y_1 \rho_1 = \text{thrust along arch at B.}$$

The horizontal pressure against A B

$$= \int_{y_1}^{y_0} p\,dy = w \frac{y_1{}^2 - y_0{}^2}{2} = \mathrm{H} = w y_0 \rho_0 . \quad (51)$$

The thrust along the arch is constant, or

$$\mathrm{T} = \mathrm{H} = \mathrm{V}.$$

The rise A O ($= a$), the depth A Y ($= y_0$), and the radii at A and B (ρ_0 and ρ) are connected by the following approximate equations. The co-ordinates of B being x_1 and y_1, let

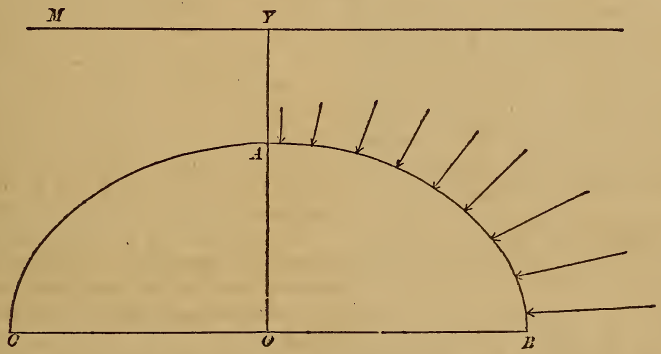
$$b = x_1 + \frac{x_1{}^2}{30\,a}. \quad \text{Then } y_0 = a \frac{a^3}{b^3 - a^3} \qquad (52)$$

$$\rho_0 = \frac{y_1{}^2 - y_0{}^2}{2 y_0} = a + \frac{a^2}{2 y_0} = \frac{a}{2}\left(1 + \frac{b^3}{a^3}\right) \quad (53)$$

$$\rho_1 = \frac{y_1{}^2 - y_0{}^2}{2 y_1} = a - \frac{a^2}{2(y_0 + a)} = \frac{a}{2}\left(1 + \frac{a^3}{b^3}\right). \quad (54)$$

The line of pressures in a hydrostatic arch, since T is constant, is *parallel* to the soffit, as in circular arches.

FIG 45.



Example.—Suppose the span to be 50 ft. (Fig. 46) and the depth A Y = 16 ft.

Find first the rise A O. In Eq. (52) $x_1 = 25'$ $y_0 = 16'$, and a few trials show that a = rise = 20′ about.

Hence

$$\rho_0 = 32\tfrac{1}{2} \text{ ft. and } \rho_1 = 14.1 \text{ ft.}$$

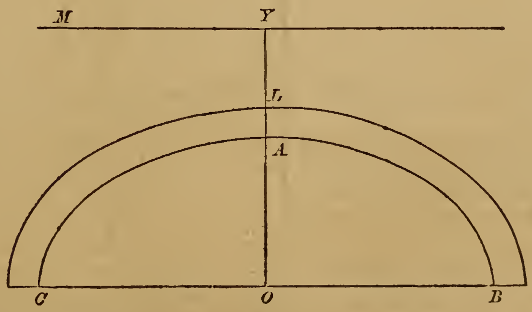
With these data describe the curve of the soffit—the radius at any other point besides A and B being given by the equation

$$\rho = \frac{y_0 \rho_0}{y}.$$

The thrust at A = H = $w y_0 \rho_0$. Here w = 62.4 lbs.

$$\therefore \mathrm{H} = 32448 \text{ lbs.}$$

FIG. 46.



The rule for the depth of keystone in a single arch gives

Depth A L $= \sqrt{.12 \times 32.5} = 1.9$ ft.

This is ample. It only gives about 120 lbs. per sq. in. as the pressure at the crown.

T being = H, the depth of the arch-ring may be uniform.

(2) The hydrostatic arch is also used when the loading is homogeneous masonry up to the extrados M Y, *provided the spandrels be suited to sustain a horizontal thrust at each point of the arch equal to the vertical load at that point.*

As all stone or brick arches sink at the crown when the centres are removed, they will exert at other points an outward horizontal thrust. Now if we assume that this horizontal thrust is at every point equal in *intensity* to the vertical loading at that point, the curve of equilibrium under such a system of forces is the hydrostatic curve. This is the assumed condition of the forces acting in the Neuilly and other bridges of this class.

When the spandrels cannot be made firm and solid this form should not be used, but when they can be, as in the successive arches of a stone bridge, it is advantageous rather than otherwise, to have such a thrust from the arch against the spandrel; while the hydrostatic curve of given span and rise gives a greater *water-way* than the corresponding catenary would.

The catenary needs no resistance from the spandrel, being balanced under the vertical load alone.

Example.—Let the span be 100 ft. and rise 30 ft. Then the depth of loading at the crown (= A Y, Fig. 46) will be found from equation 52

$$= y_0 = 7\tfrac{1}{3} \text{ ft.}$$

Then $\rho_0 = 91.7$ ft.

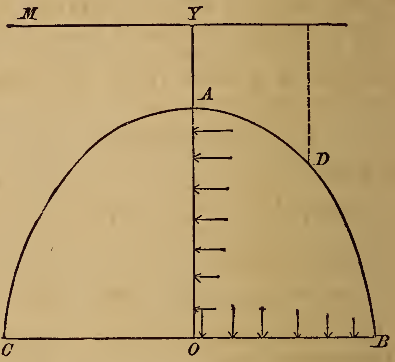
Hence $H = w y_0 \rho_0$ (putting $w = 160$ lbs.) $= 107600$ lbs.

Depth of keystone

$$= \sqrt{.12 \times 91.7} = 3.3 \text{ ft.}$$

This gives a pressure of 32,280 lbs. to the sq. ft., or about 225 lbs. to the sq. in.

FIG. 47.

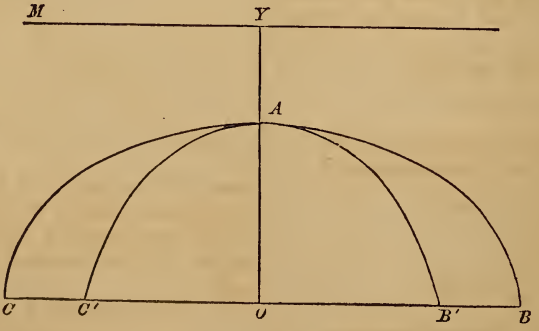


6. If the vertical forces vary as in the hydrostatic arch, and the *horizontal* are not equal to them, but differ at each point in a constant ratio, the curve of equilibrium (Fig. 47) becomes the Geostatic curve discussed in *Case VII.* This curve derives its name from the fact, that the system of pressures above described is similar to that exerted by a mass of loose earth against C A B. Let M Y = the horizontal surface of the earth; then at each point D of the arch there is a vertical pressure of intensity (p'_y) proportional to the depth (y) of D below M Y, and a horizontal pressure whose intensity is less than p'_y in a constant ratio, or

$$p'_x = c^2 p'_y$$

(c^2 being taken to represent the ratio of the intensities).

FIG. 48.



Assume a hydrostatic arch whose vertical dimensions shall be identical with those of the geostatic arch, and whose span (C B) (Fig. 48) shall be connected with the span of the geostatic arch (C′ B′) by the equation

$$C B = \frac{C' B'}{c}. \tag{55}$$

The intensity of the vertical pressure (the horizontal is like it) in this hydrostatic arch must be

$$p_y = cp'_y \,.$$

From these data deduce a hydrostatic arch, and then pass by parallel projections to the required geostatic arch.

Equations (35) (36) (37) (38) give the values of the quantities needed in discussing the Geostatic arch.

Example 1.—Let the span of the geostatic arch (C′ B′ = 100 ft.) be given; also the depth of the loading (A Y = 20 ft.); also the ratio of the pressures ($c^2 = \frac{1}{3}$); and the weight of a cubic ft. of the loading $= w =$ 100 lbs. Whence

$$p'_{y_0} = wy_0 = 2000 \text{ lbs.}$$

Then since

$$\text{C B} = \frac{\text{C}' \text{ B}'}{c} = \frac{100}{\sqrt{\frac{1}{3}}} = 172.4 \text{ ft.}$$

$$cw = 58 \text{ lbs.}$$

$$p_{y_0} = cp'_{y_0} = \sqrt{\tfrac{1}{3}}\,.2000 = 1154.7 \text{ lbs.}$$

We find from equations (52) (53) (54) for the hydrostatic arch

$$\text{Rise} = a = \text{O A} = 57.7 \text{ ft.}$$

$$\rho_0 = 140.93 \text{ ft.}$$

$$\rho_1 = 36.3 \text{ ft.}$$

$\text{H} = \text{V} = \text{T} = p_{y_0}\,\rho_0 = 1154.7 \times 140.93 = 162.700$ lbs nearly.

In the geostatic arch we have from equations (35 (36) (37) and (38)

Thrust at B = V′ = V = 162700 lbs.

" A = H′ = cH = 94300 lbs. nearly.

$$\rho_0' = 46.97 \text{ ft.} \quad \rho_1' = 62.65 \text{ ft.}$$

Example 2.—Suppose the span = 100 ft. depth. A Y $= y_0 =$ 20 ft. and rise, $a = 30$ ft. given; to find c and thence the hydrostatic arch.

From equation (52) we find

$$b = 40.71,$$

and thence in same equations $x_1 = 39$. Hence the span of the hydrostatic arch

$$= 2x_1 = 78 \text{ ft.}$$

And as c.CB = C B′

$$c = \frac{100}{78} = 1.28.$$

Then proceed as in the last example. In this example the hydrostatic arch is the smaller of the two.

The line of pressures in a geostatic arch is found as it was in the elliptic.

The geostatic is the true curve of equilibrium under earth pressure, but when A Y (Fig. 48) is great compared with A O, it approximates the ellipse described through the points C A B′ as already stated.

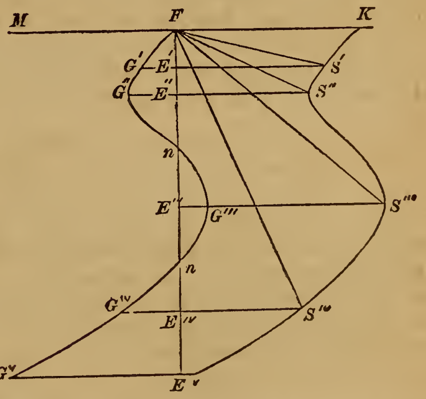
7. Convenience, or other reasons, will often dictate the form of the arch without reference to the loading, and again, necessity may make the vertical load different from any and all the cases we have discussed. In such instances Case VIII. will enable us to determine the character and amount of the horizontal forces which must be applied through the resistance of the spandrel, when once the form of the arch and the vertical load are known.

When the horizontal forces thus required are *thrusts* directed against the arch, it is generally possible so to build the spandrel that the arch may be secure, but when they are the opposite, or *outward pulls* on the arch, then it is difficult to insure stability, as to do so requires tension between the arch and the spandrel. In such cases it is best to change the form of the arch.

The discussion of Case VIII. of cords, enables us to determine the necessary data in the case of similar linear arches under similar loads.

Fig. (50) gives the geometrical construction of the triangle of forces at every point of the semi-arch A B (Fig. 49).

FIG. 50.



We may discuss a given linear arch C A B under a given vertical load, by determining:

1. Thrust at crown; which is

$$\text{H}_0 = p_0 \rho_0 \,. \tag{56}$$

2. Total horizontal thrust required on any arc A D′, A D″, etc. This, from equation (42), is

$$\text{H} = \text{H}_0 - \text{V} \cot. i \tag{57}$$

If this be negative the spandrel must exert a *pull* instead of a thrust.

On the half-arch A B the above equation becomes

$$H_1 = H_0 - V_1 \cot. i_1. \qquad (58)$$

On any arc B D^{v}, counting from B upwards, the total spandrel thrust is

$$H_1 - H = - V_1 \cot. i_1 + V \cot. i. \qquad (59)$$

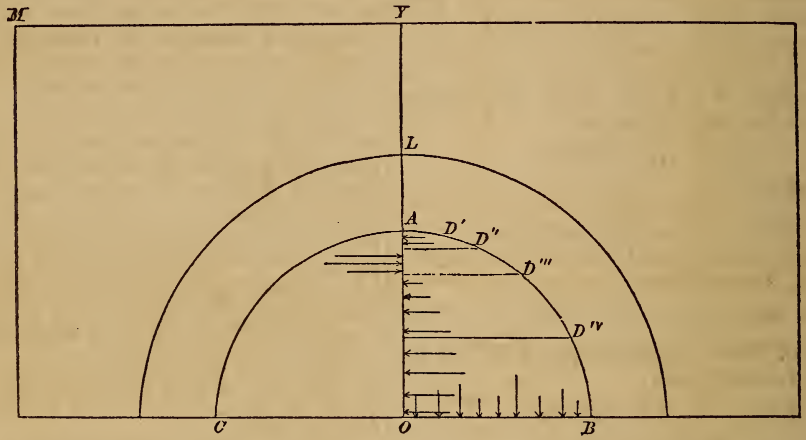
This last expression has at least one maximum value corresponding to some arc B D. In the Fig. (49) this value corresponds to the arc B D'''.

Let this maximum value be denoted by H_m and let i_m = the inclination at D'''. Then

$$H_m = - V_1 \cot. i_1 + V \cot. i_m = E''' G'''. \qquad \text{(Fig. 50)} \quad (60)$$

D''' is known as the "point of rupture." There the action of the spandrel ceases to be a thrust, and must, above that point, for some distance at least, become tension.

FIG. 49.



3. The *intensity* of the horizontal spandrel thrust or pull in any layer (as between D''' and D'^{v}) is from equation (43)

$$p_x = -\frac{d\,H}{dy} = -\frac{d\,(V \cot. i)}{dy} = -\frac{d\left(V\,\frac{dx}{dy}\right)}{dy}.$$

When H is positive (that is thrust) p_x is negative, as it should be, since it is equal to the *increment* of the abscissas of the curve F G G'', etc. (Fig. 50), and these increments are decreasing from G''' to G^{v}.

At the point of rupture

$$p_x = 0. \qquad (61)$$

We can determine the point of rupture in three ways: First, by constructing the Fig. (50) and finding the inclination (i_m) corresponding to the maximum abscissa $E'''\,G'''$. Secondly, by substituting the various values of i and V in the value of

$$(H_1 - H) \text{ (eq. 59)},$$

and getting the maximum value of the expression. The i which gives this maximum value corresponds to the point of rupture. Thirdly, by solving equation (61) $p_x = 0$.

4. The thrust along the rib at every point is from equation 40,

$$T = V \text{ cosec. } i, \qquad (62)$$

and it is represented by the inclined lines F S F S'', etc., Fig. (50).

The *horizontal component* of this thrust is

$H_r = V \cot. i$ = the abscissas of K S', etc.,

which are always equal to H_0, the thrust at the crown *minus* the spandrel thrust between A and the point in question

$$\therefore\; H_r = V \cot. i = H_0 - H. \qquad (63)$$

This is evidently a maximum at the point of rupture, or, since at the point of rupture,

$$H = H_1 - H_m,$$

we have

$$H_R = H_0 - H_1 + H_m.$$

But

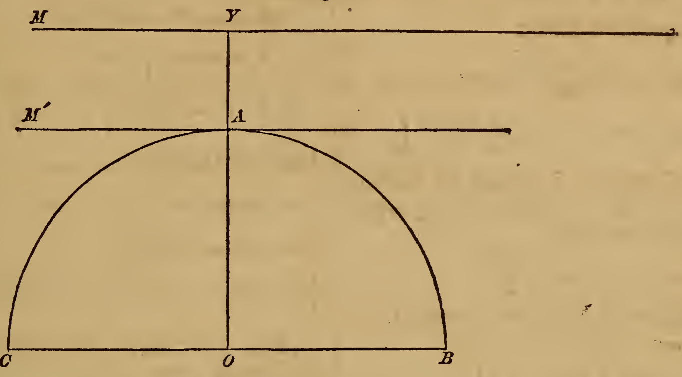
$$H_0 - H_1 = V_1 \cot. i,$$

$$\therefore\; H_R = V_1 \cot. i_1 + H_m. \qquad (64)$$

This horizontal thrust of the rib at D''' is therefore to be balanced by the horizontal reaction of the abutment at B ($= V_1 \cot. i_1$) togther with the resistance of the spandrel between B and D‴ (= H_m). When the arch is vertical at B, $\mathrm{V}_1 \cot. i_1 = 0$.

5. In single arches it is necessary to know the point of application of the resultant of the forces represented by ($\mathrm{V}_1 \cot. i_1 + \mathrm{H}_m$) in order to determine the stability of the abutments. Take moments with reference to the axis of abscissas M Y.

Fig. 51.



Then if y_{R} = ordinate of point in question, and y_m and y_1 be the ordinates of D‴ and B, we have

$$\mathrm{H}_{\mathrm{R}}\, y_{\mathrm{R}} = (\mathrm{V}_1 \cot. i_1)\, y_1 + \int y\, d\,\mathrm{H}$$

$$= (\mathrm{V}_1 \cot. i_1)\, y_1 + \int_{y_m}^{y_0} y\, p_x\, dy.$$

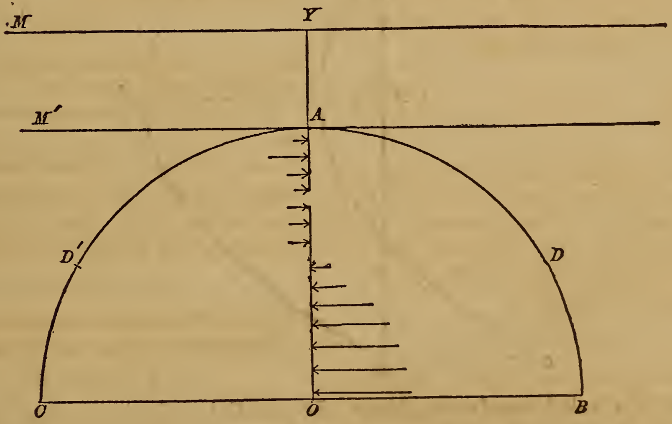
$$y_{\mathrm{R}} = \frac{(\mathrm{V}_1 \cot. i_1)\, y_1 + \int_{y_m}^{y_1} y\, p_x\, dy}{\mathrm{H}_{\mathrm{R}}}. \qquad (65)$$

In this we neglect the spandrel forces above D‴ so far as they affect the stability of the abutment. This can be done with safety.

The line of pressures and depth of keystone are determined as heretofore.

Example 1. Let the assumed form of the soffit be a semi-circle, and let the loading consist of the arch and backing of homogeneous masonry carried up to a horizontal "extrados" M Y (Fig. 51).

Fig. 52.



Place the radius of the arch = r

Depth A Y = $a\, r$

Heaviness of the material = w

Take the origin of co-ordinates at A and express the co-ordinates in terms of the inclination i of the arch as on p. 217 *Rankine's C. E.*

Then

Thrust at crown = $\mathrm{H}_0 = p_0\, \rho_0 = (war)\, v = war^2$

Vertical load on any arc = $\mathrm{V} = wr^2$,

$$\left\{ (a + 1) \sin. i - \frac{\cos. i \sin. i}{2} - \frac{i}{2} \right\}$$

Spandrel thrust on any arc A D

$$\mathrm{H} = \mathrm{H}_0 - \mathrm{V} \cot. i = wr^2$$

$$\left\{ a-(1+a)\cos.\ i+\frac{\cos.^2 i}{2}+\frac{i\cos.\ i}{2\sin.\ i}\right\}$$

On A B this becomes (since the arch is vertical at B and C)

$$H_1 = war^2 = H_0$$

$$\therefore\ H_m = V\cot.\ i_m$$

Intensity of spandrel thrust

$$p_x = -\frac{d\,(V\cot.\ i)}{dy} = wr$$

$$\left\{ (1+a)-\cos.\ i-\frac{i-\cos.\ i\sin.\ i}{2\sin^3 i}\right\}$$

The point of rupture is found by putting $p_x = o$ and finding the value of i_m by trials. As a first approximation

$$i_m = \text{arc. cos.}\ \frac{1+3a}{2}$$

Thrust along the rib = T = V cosec *i*.
At B this is

$$V_1 = wr^2\left(a+1-\frac{\pi}{4}\right).$$

So

$$H_R = V_1\cot.\ i_1 + H_m = H_m = wr^2$$

$$\left\{ (1+a)\cos.\ i_m-\frac{\cos.^2 i_m}{2}-\frac{i_m\cot.\ i_m}{2}\right\},$$

and

$$y_R = \frac{r^2}{H_R}\int_{i_m}^{90^\circ} p_x\sin.\ i\,(1-\cos.\ i)\,di.$$

Example 2.—Let

$$r = 20'\ AY = 2.5'.$$

Then

$$a = \frac{2.5}{20} = \frac{1}{8}\ w = 150\ \text{lbs.}\quad \text{(Fig. 52.)}$$

Then

$$H_0 = war^2 = 7500\ \text{lbs.}$$

$$V = 60000\left\{\frac{9}{8}\sin.\ i-\frac{\cos.\ i\sin.\ i}{2}-\frac{i}{2}\right\}.$$

$$\text{At B, } V = 60000\left\{\frac{9}{8}-\frac{\pi}{4}\right\} = 20376\ \text{lbs.}$$

Angle of rupture

$$i_m = \text{arc. cos.}\ \frac{1+\frac{3}{8}}{2} = \cos.^{-1}.6875 = 46^\circ\ 34'$$

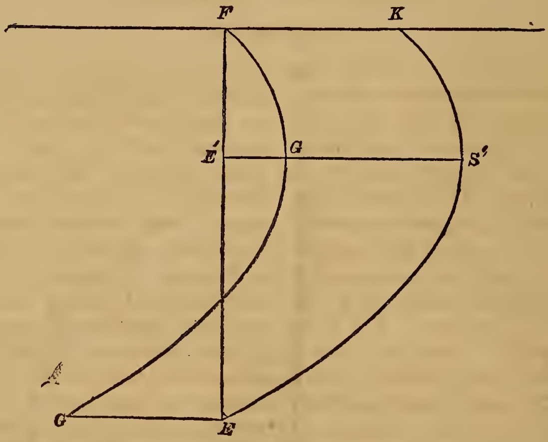
$$H_R = H_m = 60000$$

$$\left\{\frac{9}{8}(.6875)-\frac{(.6875^2)}{2}-\frac{.81\times.947}{2}\right\} = 8154\ \text{lbs.}$$

(Fig. 53) shows the manner in which the forces vary. From A to D (Fig. 52) there must be a pull in the spandrel to produce equilibrium. The total amount of this pull is small, being

$$= 8154 - 7500 = 654\ \text{lbs.}$$

FIG. 53.



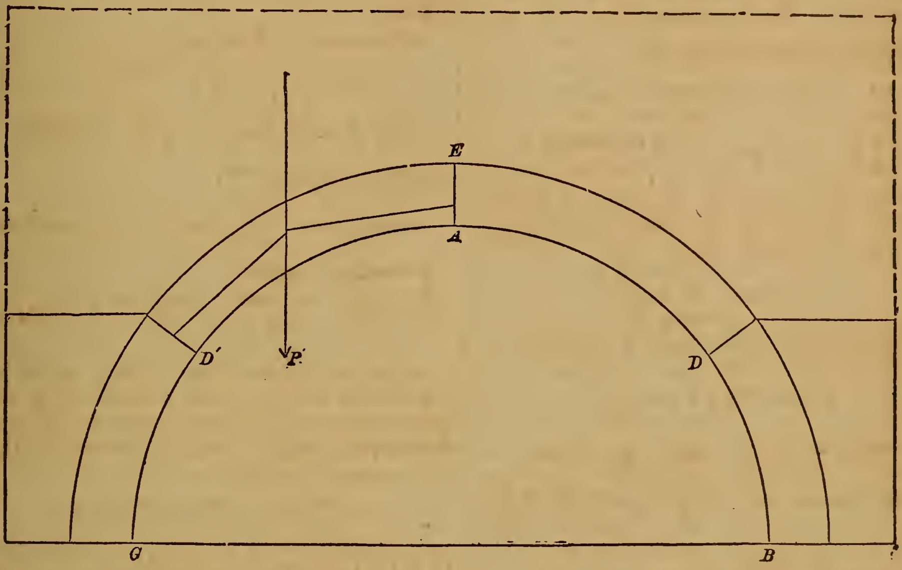
To rid the arch of it, so that the part D' A D shall either be balanced under the vertical load alone or exert a thrust outwards, instead of a pull inwards, we *flatten* the arc D' A D. A few trials will determine this flattening near enough for practice.

Thus if D¹ A D (Fig. 54) is to be balanced under the vertical load alone, find the centre of gravity of the section D¹ A and its load. Draw a vertical line P through this point, then if we can draw a line from any point in the middle third of the joint D¹ parallel to the tangent to the arch there, and from its intersection with P draw a line parallel to the arch at A which will intersect A L within the middle third, then the extreme points of the line of pressures in the section A D¹ will be within the middle third, and the line of pressures will generally be altogether within it.

The new radius required for the arc

D^1 A D may also be determined roughly by putting $H_0 = war^2 = H_R$ and thence getting r^1 since, if D^1 A D is to be balanced under vertical load alone, the horizontal thrust at every point of it must be the same and $= H_R$, the thrust at D^1 and D.

Fig. 54.



FORCE AND MATTER.

From "The Engineer."

Few men of science venture to teach that force can have existence apart from matter. To Faraday, we believe, is due the first hint at a possible conception of pure force. His utterances on the subject were brief, and intended as a species of abstract theory of magnetic influence. They have scarcely modified the current of educated thought; and at this moment no adequate conception of the existence of abstract force is to be found in the circles of science. Yet it is not, we think, impossible to form an idea of the existence of pure force; indeed, it may almost be said that we have daily evidence that force does exist apart from matter, although the presence of matter is necessary to render it evident to our senses. Gravity is, in one sense, a pure force. It is an invariable condition of, and totally inseparable from, matter, in the sense that no matter exists which is not subject to the action of the force known as gravitation. But the theorem will not work both ways. We know that masses of matter attract each other; but it has yet to be proved that a mass of matter does not exert the force of attraction, although no other mass of matter is subjected to its influence. There is probably nothing more mysterious in the whole range of material phenomena than the subtle influence which sets space at defiance, and, without any tangible link, couples the universe in bonds that cannot be broken. A force which can neither be intercepted, diverted, nor modified in the smallest possible degree, by any of the gigantic agencies of nature or the trivial influences of man's art. Gravitation is absolutely independent of all other forces, and in this respect it is to some extent isolated and unique. It is, we think, scarcely possible to realize the operation of gravitation without arriving at some crude and imperfect conception of pure force apart from matter; and however imperfect that conception may be, it will be found useful in solving some of the great problems presented to us by the operation of natural laws. Let us take it for granted, however, that force does not exist without matter, and come at once to the purpose with which this article is written. Our object is to call attention to the fact that no one has yet attempted to show the relation that exists between matter and force as regards relative quantity. It was impossible in the earlier ages that any attempt should be made to determine this relationship In the younger years of the world, manifestations of great force were always associated in men's minds with enormous quantities of matter. But as knowledge, and especially chemical knowledge, has extended, the fact begins to obtrude itself, that the absolute quantity of matter necessary to the tangible development of gigantic exertions of power may be excessively minute. Whether it is or is not possible that an accurate numerical demonstration of the relations of force and matter in the abstract will ever be arrived at, it is not for us to say. Possibly the ultimate atom may yet be found, and its measure of possible work on another atom defined; but it is certain that at present both have eluded the grasp of the highest intellects of the nineteenth century. Tyndall has gone far to determine the work done by an atom under certain conditions, but he has not attempted to define the condition of maximum atomic work, and nothing in the whole range of our subject is certainly known, except that under given conditions extremely minute quantities of matter can exert forces which almost baffle conception. A very crude popular illustration of the association of great force with little matter is afforded by gunpowder. But gunpowder really furnishes but a very indifferent example of the amount of energy which may be exerted by minute quantities of matter. A tiny drop of that curious compound, chloride of nitrogen, the precise nature of which has yet to be determined, has been known when touched to explode with such violence as to split the heavy leaf of a solid oak laboratory table and leave the apartment a wreck. Gunpowder beside this fluid is an inert substance. Fulminate of silver and nitroglycerine supply other illustrations of the power which minute quantities of matter possess under suitable conditions of rendering manifest the exertion of mighty forces. It is unnecessary, however, to seek for examples among the more recondite productions of the chemist. It is not easy to find a more noteworthy illustration of this combination of much force with little matter than that afforded by coal. One pound of good coal will liberate in combustion 14,500 units of heat. This is very easily written and remembered, but we dare to say that not one of our readers out of the hundred has ever attempted to realize what it means. The British unit of heat has been defined as equivalent to 772 foot-pounds—Joule's equivalent; the power stored up in a pound of good coal therefore represents the exertion of a force sufficient to lift 14,500 × 772, or 11,194,000 lbs., or almost five thousand tons, a foot high, or a single ton to a height of nearly a mile. Is it too much to say, with such a fact before us, that the quantity of matter required to render force manifest is almost infinitesimal. A particle of coal, indeed, so small as to elude our senses with ease, is competent to exert a very tangible power. The 14,500th part of a pound of coal is less than one-third of a grain, yet it suffices to store up a force which would lift nearly 7 cwt. through a height of one foot. If a pound of coal were divided into 11,194,000 separate parts, a powerful microscope would be necessary to detect one such part, and yet each represents as much energy as would raise a pound weight a foot high. We need seek no further for evidence that the existence of matter in quantities tangible to our senses is by no means necessary to the development of power; and we are led to ask once more whether any point can be defined where matter ceases and force remains; or is it certain that without matter in some shape or form force can have no existence, manifest or abstract?

The relations subsisting between force and matter have been powerfully brought home to practical engineers by the Blackburn boiler explosion. It is not our intention here to say anything of the causes which may have induced the catastrophe, nor are we about to enunciate any theory of boiler explosions. It is impossible, however, to read with care the report which we published last week, without feeling that a puzzle is presented to us, which can only be explained by the fact that very small quantities of matter may, under certain circumstances, manifest an energy apparently altogether incommensurate with the mass of matter employed. We have no means of knowing with accuracy the weight of water contained in the two boilers at the time of the explosion; probably it was about 25 tons. This water was heated to about 324 deg. Fah., the temperature corresponding to an absolute pressure of 95 lbs.—80 lbs. safety valve load. Each pound of water therefore represented an energy of 324×772=250,128 foot-pounds; but all this energy was not available for destructive purposes. When the boilers exploded the temperature fell instantaneously to 212 deg., leaving to be accounted for 112 deg. If this were immediately expended in one way, about one-eighth of the total weight of water in the boiler would have been converted into steam at atmospheric pressure, and no doubt in this way by far the larger proportion of the stored up energy in the boiler was utilized, and but for the invariable occurrence of the flashing of water into steam when pressure is relieved, the consequences of a boiler explosion would be more fearful than it is perhaps quite possible to realize. Here, however, as the capacity of water for storing up energy is great, that which constitutes the dangerous element in heating water under pressure becomes in some measure a means of safety. In this respect the behavior of water is totally different from that of gunpowder; when a charge of powder is fired in a gun the entire energy stored previously in the powder is exerted on the gun and the projectile. When a boiler explodes, a very considerable portion of the energy previously concentrated in the water is expended, not on the boiler, or building, but in converting more water into steam at atmospheric pressure, and it thus happens that although the destruction wrought by the explosion of a large boiler may be fearful, matters are never as bad as they would be but for the remarkable property possessed by water, of instantaneously utilizing its stored up energy in the comparatively harmless way of flashing a portion of itself into low-pressure steam. All the latent energy in the boiler was not thus expended, we know; had it been, then the mill would not have been wrecked, and no one would have been killed. A portion was expended in doing work—very disastrous work, no doubt, but none the less real. And this brings us at once to the puzzle, or puzzles, to which we have referred. We hear of stones being flung long distances, while a flue was lifted high in the air and fell on the roof of the weaving shed. Let us take this flue as typical, and ask ourselves how it was raised? The obvious answer is, "Oh, the steam carried it there." Precisely; but how did the steam carry it there? When a projectile is discharged from a gun an enormous pressure is exerted on its base for a considerable portion of time; but what are we to think of the nature and mode of action of the force which lifts a flue out of its place after the containing shell has been rent to atoms, and sends it flying through the air? Literally, not more than a few pounds of steam could find access to the flue to do the work; its surface was too small. Taking the flue at 30 ft. long, and just allowing a strip of its surface 3 ft. wide as an effective basis for the action for the steam, we have only 90 ft. surface. A body of steam at 80 lbs. pressure and 1 ft. thick over this surface would weigh about 2 lbs. only. It is impossible to imagine a sufficient velocity imparted to this 2 lbs. of steam to enable it in any way to impinge on the flue and thus propel it through the air. Nor shall we be helped if we say that the pressure beneath the flue was unbalanced the moment the shell burst, and this unbalanced pressure lifted it. The pressure must have operated for a considerable time after the flue started on its flight, otherwise no energy could have been stored in it to enable it to continue its ascent. To what then are we to look as the direct cause of the ruin which attends a boiler explosion? Where is the link between the energy stored in the water and the walls blown down at a distance, the scattered bricks of the seating and the flying boiler plates? We do not think it too much to say that these questions have never been answered, and that the effects developed are perhaps after all manifestations of the exertion of force by the aid of very minute quantities of matter, operating in a way which is not quite understood. The cause of a boiler explosion is one thing, the cause of the effects of an explosion is quite another. We hold now, as we have always held, that there is nothing occult about the reason why a steam generator bursts. Neither, perhaps, is there anything mysterious about the flying of plates and the loss of life, and the ruin of buildings; but it is quite certain that no solution yet put forward has proved capable of that accurate numerical demonstration which can alone insure its acceptance. That ruin ensues when a boiler bursts we know, but we do not know whether a flying brick flies because it has been subjected to intense pressure acting through a limited space for a short time, or whether it is carried on a blast of steam as a leaf is carried by the wind, or whether it is driven by energy transferred from a mass of water moving, and whose movement the luckless brick has checked. Nor is it quite certain—although, in deference to accepted opinion, we have spoken as though it were certain—that the first effort of energy set loose in the rent boiler is to convert more water into steam, and not to manifest itself in some other way which is apparently occult, but only so because very little is really known about the manifestations of energy, or the bond which exists between force and matter.

TARGET'S SEWERAGE SYSTEM.

From "Engineering."

The multiplicity of plans which have been brought out for the purpose of removing and disposing of the waste or refuse of human life, together with that of the lower animals, is an evidence of the difficulty which surrounds the entire question. This difficulty may be viewed in its mechanical, chemical, and financial phases, and each of these has its complications, owing to the variety of local conditions which have to be satisfied. In the case of places situated near the sea, a long sewer running to a point, a little below the low water level, is generally depended on to get rid of all liquid refuse, while the solid matters, such as ashes, etc., are generally used on adjacent land, or for brick-making. Towns placed near rivers, have, as a rule, in all parts of our own and other countries, used the stream as the receptacle of refuse of all kinds; and in places where no adjacent river or even brook is available, all the liquid refuse has been thrown into cesspits or ponds, or, in fact, any hollow place, without the slightest reference to the dangerous consequences that might ensue. In regard to the "dust-bin" refuse, including not only ashes but decomposing vegetable matter, etc., a glance at some of the vacant ground in the suburbs of London and other large towns, will at once explain its disposal by a common notice that "Dry rubbish may be shot here;" and on this rubbish a large number of new streets has for years been built to the detriment of public health.

The sewage question, *per se*, has been largely dealt with in our present and preceding volumes, chiefly in regard to the water-closet, midden, and other recipients of refuse, and the individual means that have been proposed, by irrigation, precipitation, and other methods, to deal therewith, have been explained. In the present article we propose to deal with the subject in a comprehensive point of view, even at the risk of apparent repetition of some matters which have been, in previous articles, somewhat fully discused. For this purpose we may first inquire as to what refuse has to be dealt with, in all classes of towns, whether of a social, agricultural, or manufacturing character.

Wherever the water-closet system has been adopted there has been a large dilution of the urinary and fæcal matter prevalent, dependent partly on the amount of the water supply afforded to each house, but perhaps still more so on the habits of its inhabitants. As a rule, the intermittent system is for the present the mode of supply in many parts of the United Kingdom, but now the constant supply is being gradually adopted, attended with an actual saving on the previous amount of water used or wasted. This is a matter of no surprise considering that where butts and cisterns have prevailed, the tenants, generally, have considered it their duty to use all the daily supply afforded them, and besides, there is the loss caused by defective ball-cocks, taps, etc. This loss to the water companies, however, may have resulted in social benefit by the continual flushing of the sewers which has consequently taken place.

But in many places the water-closet system is all but unknown, and hence the use of privies, middens, etc., in which the human excrementitious matter is literally stored, in each household, perhaps for months or even years. The ash-pit is either separate from, or adjacent to, the privy; the other liquid house refuse being usually cast into the streets to run down the sewers or to fester during the hot weather in the open air, poisoning the inhabitants on either side of the street. Yorkshire, Lancashire, and a large proportion of Scotland present this in its worst state, at the present day. The only means of removing all classes of refuse in such places from the house is that of cartage, which is at the same time expensive, a dangerous nuisance, and very imperfect in its action. All or most of the agricultural districts also fall under this category.

Lastly, the disturbing element of manufacturing operations appears. Generally these are never carried on when sewers alone can be depended on for conveying away the refuse, except as an adjunct to adjacent rivers, which are made directly or indirectly the recipients of a series of waste products which it would defy the most profound chemist to enumerate, let alone describe. Usually in all manufacturing towns the privy, cesspool, and ash-pit are the chief receptacles of house refuse, with a mere sprinkling of water-closets.

From these sources we derive all the refuse which engineering and chemical science and art have to contend with in solving sanitary questions. Consequent on the varying conditions, qualities, localities, etc., of such refuse, numerous schemes have been adopted or proposed, which may be shortly stated as follows: For the purification, disposal, and utilization of sewage, those of irrigation, filtration, and precipitation; for dealing with urine and excreta alone, Moule's, Goux's, and similar dry-closet systems, all of which require the separate removal of ashes; and the latter both the separate removal of ashes and house-slops; while last may be mentioned the tub system, by which all the house refuse is removed weekly, or at shorter intervals, from the place of deposit to be subsequently disposed of as manure, etc. Scott's system, as now practised at Ealing, and experimented on at Birmingham, has the distinctive feature of dealing with the sewage by using lime as a precipitant, and converting the resulting residue into cement; the house ashes he, however, leaves untouched. In this *résumé* of all the leading systems we have omitted both names and details, as they will be found *in extenso* in our two last volumes.

By careful examination of all the existing schemes of removing, disposing, or utilizing sewage, excreta, ashes, etc., it will be seen that each has only a partial adaptation to the entire purpose, leaving something to be supplemented by separate methods, excepting perhaps the tub system, as followed at Rochdale, etc., by which all except manufacturing refuse is removed, that being left to pass into the sewers, together with the rainfall and street waterings.

To meet all the necessities of the case we have now to draw attention to a very comprehensive scheme suggested and patented by Mr. Felix Target, of which a general outline was given in our two preceding volumes by means of letters furnished by that gentleman. He divides his method into two departments, namely, that of closet receptacles, and the removal of the deposit to works; in which, secondly, such deposit is converted into a portable concentrated manure in the form of an ammoniacal salt.

He proposes to collect, or rather receive, the liquid and solid excreta, in such a manner that the urine shall be voided in a separate chamber from the fæces, under the assumption that the two are naturally voided separately at an angle of about 45 deg. He employs in such closets an absorbent for taking up the fæcal product, using for the purpose straw, chaff, screened ashes, peat, etc. This receptacle he terms an "eccentric divisor," or "E. C. closet." The mechanical arrangement of this is such as to permit it to be placed under any already existing privy seat. The receptacle may be removed every week or fortnight, according to the extent of its use. For indoor use, sick-rooms, etc., an arrangement is made by which, at each time of use, the disinfection or deodorization of the excreta is effected. This is made automatic by providing a movable seat hung on sash centres, depressed in front and raised at the back. By means of an india-rubber spring, a certain amount of disinfectant matter is caused to fall on the fæces, at each time the "closet" is used, when the occupier removes from the seat; and the action is repeated on each occasion of the seat being used, provision being made for about 100 times. The urine is collected apart from the fæces. The inventor suggests the use of sawdust as the absorbent combined with any kind of disinfectant. The advantage of this arrangement consists in its not being liable to get out of order, and consequently its action is regular and to be depended on. For collection from several houses, built in blocks, Mr. Target suggests an arrangement by which the whole essential features of the plan can be carried out, but avoiding the necessity of separate or house-to-house collection. His great object, as will be subsequently shown, is that of carefully collecting the urine apart from the fæcal matter. In respect to the collection of ashes, kitchen refuse, etc., he proposes daily calls on the part of the scavenger, whose approach should be announced by a bell, the house refuse being placed outside of the house in a tub or box, and thus the dust-bin would be avoided To prevent any annoyance in regard to emptying closets separately, he suggests that pipes may be laid from the closets of several houses into a common cistern, whence the urine, etc., may be pumped into carts for their removal. This method would of necessity be much more economical than that of house-to-house collection. But besides, there is the advantage of preventing the overflow of tubs, now used in some places, as a system which occasions much nuisance, dirt, and even danger to health.

Thus far we have described the chief points of Mr. Target's plan in regard to the collection and removal of house refuse, but the most important part, that of its conversion into a profitable commercial product, has to be dealt with.

For successfully carrying this out Mr. Target depends on the fact that the fæcal matter is of much less value than the urine. He, therefore, bases all his methods on their separate collection in the closets or receptacles at the moment of their voidance, dealing with fæcal as a solid, and the urine as a liquid. He estimates, making various allowances for loss, etc., that 24 oz. of mixed excreta may be collected daily from each individual in an average population of, say, 100,000 persons, which would consequently give, daily, about 11 tons 3 cwt. of fæcal matter to 58 tons 12 cwt. of liquid matter (urine), or in round numbers something like 70 tons.

It is presumed that each of these products has been collected separately, by means of the divider closet, the fæces having been mixed with the absorbents and disinfectants. The receptacles when full are to be conveyed in closed vans to the works. The fæcal or solid matter is then to be incorporated with coal tar, and then moulded by suitable machinery into blocks or bricks. These blocks are then to be air-dried, in the manner usually followed in house-brick-making, and thus, in a few days, they will become suitable fuel, to be used in place of coal for further operations. It will thus be seen that Mr. Target proposes to utilize all the carbon of the human excreta for heating purposes, and thus to economize this cause of expenditure.

The next step is that of treating the urine so as to extract from it, in the most economical and effective manner, all its nitrogen in the form of ammonia, and the subsequent conversion of this into sulphate of ammonia as a manure now so greatly in request; or, if desirable, to produce ordinary sal-ammoniac, which is largely employed in metal and other manufactures. The urine is heated with caustic lime in a closed apparatus and the ammonia given off is received into sulphuric acid, if sulphate of ammonia be required, or into hydrochloric acid if sal-ammoniac is to be produced. Generally the plan followed would be that adopted at gas works for similar purposes; but Mr. Target's method of economizing fuel, by using the "bricks" made from the fæces, and the gases evolved in their combustion, as a source of heat, will nearly, if not entirely, do away with the use of coal. In fact, he calculates that the 11 tons of fæcal matter mixed with an adequate proportion of tar, as already described, would render any other fuel needless. This is a most important point, because the cost of the fuel is the element on which the success of the entire plan, in a commercial point of view, depends. Equally so is the method by which the heat produced is applied, and to effect this in the best manner Mr. Target has invented a still in which all such conditions are rigorously carried out.

Next comes the important point of the financial part of the affair. Entering into careful calculation of the expenses of collection, removal, and manufacture, including all items of expenditure for wages, etc., Mr. Target puts the cost of the conversion of the excreta of a population of 100,000 persons at £50 per day, which would be covered by the amount of sulphate of ammonia daily produced, leaving many other products that might be utilized, including phosphates, alkaline salts, etc., derivable as residual products both from the fæces and urine.

We have thus epitomized the leading principles of Mr. Target's method, as applicable to large towns. Some of the details are not new, but the combination of them and others presents several novel features, but especially that of economy in manufacture. By all previously described methods, a large proportion of the nitrogeneous products of the human system is lost, and to prevent such loss is Mr. Target's object. It is evident that the whole system must be subject to certain modification, according to the locality in which it is to be applied. In districts where the population is highly fed, the products will be much more in quantity and therefore in value, owing to the presence of more nitrogenous matter than could be gathered from poorer districts. In some places, slack coal, being very cheap, might be used, and the fæcal solids be sent out as dried manure, while in others they would be employed exclusively as fuel. It is a great advantage of the plan that it can be used under such varied conditions. Another and highly important point is that the sulphate of ammonia formed is of such high commercial value as to make the question of its cost of carriage insignificant, no matter what the distance may be, and in this it compares most advantageously with all the manures yet produced by chemically precipitating sewage, for they generally contain, at least, three-fourths of their weight of matter positively valueless and inert. The sulphate of ammonia, again, is a product that does not change by keeping, and its demand in the market is almost always in excess of the supply. It at present fetches from £15 to £17 per ton.

We are not aware of a single instance in which the disposal of sewage and other refuse has yet been effected but at a cost to the ratepayers, except perhaps in one or two cases in which irrigation has been followed rather as a fancy than a business. All the chemical schemes have notably failed, and the tub system has entailed much cost where it has been adopted. It is true that the chief problem is not so much how to turn the sewage of towns into money making, as how least injuriously and with most economy to get rid of it. But if this can be done in a manner which, while affording no profit, may at least cover the entire cost, the advantage will be enormous. This Mr Target proposes to obtain. The authorities of most of our towns are utterly at a loss how to get rid of their sewage, and this new method, or rather combination of methods, affords a good chance of solving the problem in a sanitary and financial point of view.

METROLOGICAL REFORM.

From "The Engineering and Mining Journal."

We regret that we have not space for the publication at length of two memorials issued by the American Metrological Society, addressed to Congress and submitted for signature to all persons who sympathize with their object. In one of these memorials the desirability of a uniform system of weights, measures and moneys, is set forth, and reference is made to the fact that the inhabitants of France, Belgium, the Netherlands, Spain, Portugal, Italy, Switzerland, Roumania, the entire German Empire, and, for purposes of foreign commerce, the Austro-Hungarian Empire also, enjoy the benefits of uniform metrological standards, and that the same is the case in all the countries of South America and in those of North America south of the United States. Great Britain and this country are almost the only ones that hang back, and there are numerous indications that they cannot long resist the general tendency. Ten years ago, the optional use of metric weights and measures was legalized by the British Parliament in Great Britain and Ireland; and in legislating for India and its population of 150,000,000 souls, the British authorities have actually adopted the metric system.

Congress has already taken several steps in the same direction. In 1866, the use of metric denominations was legalized and the General Government has caused to be prepared and delivered to the several States accurate copies of the metric standards. Moreover, in the coinage act of last year the weights of all silver coins of the United States, except the trade dollar, are stated in metric denominations. This memorial asks for such additional legislation as shall make efficient the measures already taken, and familiarize our people with the metric system in ways not calculated to disturb their ordinary business. Laws are asked for, which shall make practicable as well as legal the use of the metric system of weights and measures in the estimation and computation of customs-duties in the custom-houses of the United States; which shall make it obligatory upon the Post-Office Department of the United States to assess postages on matters transmitted through the mails in accordance with the provisions of the metric postal act of 1866; which shall require, in the reports of all the great public works conducted under the authority of the Federal Government, numerical statements involving dimensions, or quantities of any kind, to be made in metric denominations as well as in those of the metrology in common use in the country; and which shall extend this requisition to statistical and other documents involving statements of quantities, which may be issued under authority of any of the departments of the Executive Government.

The other memorial refers to coinage, and asks that the legal weights of our gold coinage, which are already metric within a fraction exceeded, for the smaller coins, by legal tolerance, may be made entirely metrical, so that the amount of pure gold contained in the gold dollar will be exactly one gramme and a half. This statement of the case is correct, but meagre. The numerous reasons for a change are not given with sufficient fulness; nor is it pointed out, that if the gold dollar contains exactly one and a half gramme of pure gold, then a three-dollar piece, nine-tenths fine, would weigh exactly five grammes. The coinage itself, therefore, as well as the amount of pure gold contained in it, would be commensurable with metric standards; and it would be easy, by printing upon each coin a statement of its weight, to make everybody familiar with the units of weight. This opens at once an easy road to international coinage. It is only necessary that the fineness of standard gold should be everywhere nine-tenths (as it is everywhere already except in Great Britain), that the weight of pure gold in coins should be given on the coins in metrical units, and that the mints of civilized countries should do honest work. The immediate result would be, that the gold coins of nations adhering to this plan could safely be made legal tender in exact proportion to their weight. For instance, in this country foreign coins could be accepted without indirect calculations of value, on the simple principle that every three grammes of pure gold would be worth two dollars, or that five grammes of standard gold would be equivalent to three dollars. And the ultimate result would be that the gramme of pure or standard gold would become the world's unit of money, superseding, by the most natural and inevitable process, all local units, or co-existing with them.

We wish these points, and others that could be named, had been more explicitly set forth; but in spite of such minor deficiencies we heartily coincide in both memorials, and trust that they will be so numerously signed as to produce a tangible effect in legislation. A copy of each memorial may be found at this office, and persons in sympathy with the objects of either are cordially invited to sign it here.

A Novel Condenser.—We notice that a M. Körting has invented and introduced a novel condenser, in which the work required to eject the condensed water is performed by its own velocity, instead of by the old-fashioned air-pump and hot-well. The condenser is of the old injector form and principle, in which the exhaust steam is admitted by various concentric cones around a stream of falling water. This disposition of parts causes the exhaust steam from any cylinder to offer a large surface to the cold water. Condensation is thereby effected, and a very considerable velocity is produced in the descending column of water. This causes a considerable vacuum behind the falling column. In order to produce the required effect, it is necessary that the falling water should have a small initial velocity. In M. Körting's arrangement the water has a velocity due to a head of three metres. The water is pumped up into a tank at that height by means of a pump attached to the engine; so that the power required to work this pump must be deducted from the effective gain of the condenser. The advantages of the apparatus are thus summed up:—

1st. Its price is not more than from an eighth to a quarter of an ordinary condenser. 2d. There is no need for any foundation, and consequently it is easily applied to existing engines or to new ones. 3d. It works without air-pump, which serves the loss of work and the inconveniences of setting up and of operation of the latter. 4th. There is nothing to regulate, and in consequence it demands no particular care from the attendant. 5th. As there are no moving parts (piston, valves, etc.), there is no wear, repairs, or interruption in work. 6th. Its application is especially advantageous to small machines, where the inconvenience and the price of an air-pump is very great.

COAL SUPPLY AND THE IRON INDUSTRY.*

By I. LOWTHIAN BELL.

From "Engineering."

The greater portion of the habitable surface of our earth is of such a temperature as to require for the comfort, and indeed for the health of the human family, the development of artificial warmth. In tropical climates this necessity is of rare occurrence, but even there the agency of fire is constantly had recourse to for the preparation of food, however rude and simple a process this may be. The absence, then, of the means of producing heat artificially, certainly in regions of moderate temperature, would practically be equivalent to unfitting them to serve as the abode of man.

Human life, it is true, is susceptible of being maintained, even in the most northern latitudes, with the assistance of a very small amount of combustible matter. In the Arctic regions, for example, where vegetation in the higher forms is entirely wanting, the fuel used is devoted exclusively to culinary work, the animal warmth of the inhabitants being maintained by the family living in a small, and consequently overcrowded apartment. As an accompaniment to this mode of life, no doubt the health of all the occupants of such dwellings must suffer from the unavoidable vitiation of the air they are breathing.

It is needless to remind this meeting that whatever might be the condition in respect to civilization of a nation, wood in the first ages of its history was the only fuel made use of, obtained quite readily from the forests which, in by far the greater majority of cases, would everywhere abound. For the purposes of agriculture and for habitations, these would be partially cleared away, but that which remained would far more than suffice for the wants of a thinly peopled district. It is nevertheless consistent with actual experience that perfectly civilized nations can, not only exist, but carry on various industrial enterprises, and yet be entirely dependent for the fuel they require on the forests, which more or less still cover the face of their respective countries. Thus, both Norway and Sweden occupy a position of some importance as iron-producing communities, yet, in both of these, charcoal is the exclusive source of the heat required in the furnaces and forges.

In neither of the nations just mentioned can we connect the importance of their position as iron manufacturers with a large production of this indispensable article of civilized life, for some individual firms are to be found in this empire who deliver to commerce as large a weight of the metal as is produced in all Norway and Sweden combined.

It is probably due to the fact that industry can thus be maintained independently of mineral fuel, which has given rise to a recent suggestion, that the day might come when nations which have partially or entirely abandoned the use of charcoal, might find themselves constrained to devote their attention once more to the growth of timber as a means of commanding temperatures of artificial production. However practicable this may be in countries where the soil is incapable of being put to other uses, it may be dismissed at once from one like our own, even were the land not required for food-producing purposes. Indeed it may be safely said that no people could long carry on large manufacturing operations where forests were to be the sole sources of the fuel required.

In illustration of this, imagine one of our modern blast furnaces placed on the edge of a forest. Such is the quantity of combustible it devours, that by the end of the first year of its existence about 1,400 acres of trees would have been felled to satisfy its requirements, or a space more than 2 miles long by a mile in width. Compare this with the powers of a mine, from an ordinary seam of coal, in which 5 or 6 acres would give as much available fuel for smelting purposes as these 1,400 acres of wood.

No doubt the forest possesses a quality not to be found in the mine, for while an interval of 30 or 40 years is sufficient to reproduce its trees, a seam of coal, once robbed of its treasure, is exhausted forever. Not even this disadvantage, however, can be held as being of much account with a nation such as Great Britain. I arrive at this opinion by finding that our blast furnaces alone, which only consume

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* From the Address of I. Lowthian Bell at Manchester.

about one-sixth of the coal raised in this empire, would require for their use a surface of more than 20,000 square miles covered with grown and growing timber, which is nearly one-fourth of the total area of Great Britain. Independently of the impossibility of sparing such a breadth of land for such a purpose, it is evident the mere conveyance of fuel to be collected over such a wide-spreading space would render the manufacture of iron, as it does elsewhere, an undertaking of great cost and extreme difficulty.

This liability to exhaustion of our coal-fields has, very properly, conferred upon the question of fuel supply in this country a great and increasing importance. To such an extent did this prevail, and rouse the national fears thereon, that measures were in contemplation for the extinction of the National Debt, which had to be paid off previously to our coal being consumed; otherwise it was justly feared that the security held by the country's creditors would be materially reduced in value by the decadence of an industry which would inevitably accompany a want of fuel.

A Royal Commission was appointed, and as a result of their labors the nation has been assured that with an increase of something like 25,000,000 tons upon our present annual demand, we have enough to serve us for 1,000 years, so that neither we nor any immediate Chancellor of the Exchequer need be under any pressing alarm as to our ability to pay our debts in full, so far as this is affected by the possession of coal.

Notwithstanding the satisfactory character of these investigations, conducted by very competent men, almost within twelve months of the completion of their work, we have coal rising to and continuing at a price, which nothing short of a prevailing and permanent famine would appear to justify. For this apprehension I firmly believe there exists no necessity. There is, no doubt, coal enough to last for many generations to come, and additional fields are being discovered, which in all probability will greatly add to the powers of production laid down by Her Majesty's Commissioners in their Blue Book, which contains at ample length the basis of their calculations. It is obvious, of course, the price of a commodity may be influenced by one or two causes; it may either rise in value from actual scarceness, or from an increased demand for its use. The recent, and even the present extraordinary high cost of coal has arisen from a combination of these two causes, but the former certainly is not in any way connected with any approach to that exhaustion of our natural powers so much dreaded a year or two ago.

Fuel forming so indispensable an item in the expense of most manufacturing processes, it is clear its cost to the consumer is a matter of first importance in placing him in a position to compete with other nations. At the same time I am very far from thinking, looking even to a future of no remote distance, that very cheap coal is not an unmixed benefit. Not only does its low price render us unmindful of waste, but the very circumstance of cheapness renders it inexpedient, because unremunerative, to make any attempt to introduce means and appliances for its economy. Within my own recollection vast quantities of small coals were supplied to the chemical and iron works on the banks of the Tyne for less than two shillings a ton, a state of things which it is needless to say afforded no margin or inducement to the manufacturer to cease being careless in its application.

One result of this profuse expenditure of fuel is, no doubt, being felt in many instances, even in our time. As a rule, the least expensive coal is the first worked, and by just as much as we have wasted our most economically-wrought mines, have we wasted the country's resources to an extent represented by the difference between these and others involving a greater cost of extraction.

Without any reference whatever to the exhaustion of our beds of coal, there are other circumstances which may seriously impede the industrial progress of a nation, and among these not the least important is the want of labor to meet the numerous requirements which a constant demand for an increasing market may entail. So long as the population of a country is in excess of this demand, no enterprise will ever fail for want of the human hands needed for its prosecution, but the moment every one is actively engaged it becomes a question of imperial importance and necessity that as few men as possible should devote their energies to an occupation which might be dispensed with under a different condition of things.

Ultimately, no doubt, as we are taught

by the laws of political economy, such a disorganized state of things as would ensue from an excessive price of coal would find its own level, but to ourselves at what cost? I have known railway bars sold at such a price as would now barely cover the price of the coal required in their manufacture. Let us suppose a country like the United States entering the market against us, as it now, with our enhanced price, is doing largely. This country possesses an extent of territory capable of furnishing the means of supporting countless bands of workmen. It has iron ore in great abundance, and known coal-fields thirty times as large as our own. If, in our case, where the existence of mineral fuel has been known at least 2,000 years, we are still discovering fresh beds of coal, we may regard North America as little likely ever to run short of the means of heating its furnaces as we stand in danger of not being able to build houses for want of stone.

From the fact of iron absorbing nearly one-third of the entire coal raised in this country, this trade would first feel the pinch, and, by the extinction of a portion of our furnaces, we would relieve the fuel required for their use, and enable it to be applied to other purposes, which could better afford to pay the enhanced price.

There are, no doubt, many disturbing causes which render the investigation of such a question as that under consideration one of extreme complexity and difficulty, but I trust enough has been said to prove that an avoidable waste of coal is a national sin, an injury to ourselves, and a great injustice to our successors.

I fear, in spite of what has been done to reduce this waste, still much more remains to be accomplished, and therefore it would be difficult to conceive a more appropriate start for a society established for the promotion of scientific industry, than an exhibition of appliances for the economical consumption of coal. It is appropriate, because economy in consumption is, as we have seen, of national importance, and because no subject which engages the consumer's attention is more dependent on science for a proper appreciation of the laws which regulate combustion, and for a knowledge of the effects produced by burning fuel.

Of the 120,000,000 tons of coal raised annually in this kingdom about 20,000,000 are now used in the manufacture of crude pig iron. It is a branch of our national industry which furnishes a ready and striking example of the danger which attends the pursuit of similar undertakings without that assistance which science is alone capable of affording. It will be within the knowledge of many of this meeting that, although the earliest record we possess indicates the existence of iron to have been well known in the remotest ages, it was exclusively in its malleable form that this substance was known to the human race. It was obtained in this condition by means of rude furnaces, 2 ft. or 3 ft. high, and, in the hope, probably, of saving fuel, these pigmy structures were increased in height until the change of conditions permitted a portion of the carbon of the charcoal to unite with the metal and form cast iron. The experience gathered from this course of procedure gave rise, about the sixteenth century, to the so-called blast furnace. In the earlier forms of this well-known apparatus, by far the greater portion of heat generated in the hearth would be carried away by the great volume of highly-heated gases arising from the combustion of the fuel. Our ancestors would doubtless find that by increasing the height of the column of matter they were operating on, a part of the escaping heat would be intercepted, and combustible in consequence would be economized. Successive additions led to iron furnaces being built 40 ft. or 50 ft. in height, and so they were left until within the last dozen years. Now had any ironmaster, previously to the introduction of the hot blast in 1828, ascertained by chemical analysis and observation the composition and temperature of the gases escaping from one of his blast furnaces, he would have learned that, independently of the imperfect combustion he was effecting, there existed in the form of sensible heat in these gases a value far more than that due to half the fuel he was burning.

A knowledge of this fact was either wanting, or its significance was unheeded, and notwithstanding the experience gained by gradual additions to the dimensions of our furnaces, it is a little remarkable that it is only within the last ten years that we learned that a simple addition to their height enabled us to save fully one-half the fuel formerly required.

In the mean time, *i. e.*, abour forty-five years ago, it occurred to the mind of Neilson to heat the air before it was propelled into the furnace. This was accompanied by such an enormous saving of fuel that all kinds of explanations were given to account for the apparently miraculous effects of the hot blast. The true one, as I believe, is that by reducing the volume of gaseous matter flowing through the contents of the furnace, more time is given for it to raise the temperature of the materials and to effect the reduction of the ore under treatment. The absence of this knowledge has led ironmasters in the meantime to incur large outlay in the construction of costly apparatus for heating air, while the same effects might in many cases have been just as easily attained by simply adding 20 ft. to the height of the furnace.

These remarks might appear to indicate an opinion that the application of hot blast in the manufacture of pig iron may now be dispensed with. This is not my meaning, for by the use of the gases formerly burnt for no useful purpose at the throat of the blast furnace, the air used in the process is heated and adds to the general economy of the process, although in a much less striking degree than happened at the time Neilson made his discovery.

As the most prominent instrument which has placed this country to avail itself of its natural advantages, we should have unhesitatingly to point to the steam engine. By means of this wonderful invention you were informed by your noble President, in his inaugural address, that the inhabitants of these small islands were doing the world's work equal to the producing power of one-half the entire population of the globe we live upon. Now the steam engine, after all, is a mere contrivance to apply through the instrumentality of water the motive power of heat stored up, in our case, in the forests of bygone ages. Heat is now considered a form of motion, the two words being convertible terms; but of this I need scarcely remind a Manchester audience, for among the distinguished philosophers who have labored in this most interesting and important field of natural science, there is not to be found a more illustrious name than that of your fellow-citizen, Dr. Joule, to whose remarkable labors we are indebted for the knowledge of how much heat, and therefore how much fuel, is required to call into operation any given amount of motion or power.

The acquaintance of natural laws thus placed at our disposal by the persevering patience of this distinguished engineer, informs us of someting which cannot fail to be somewhat distressing to our national pride, for by its means we learn that our best steam engines only afford 10 per cent., and very many under 5 per cent. of the power the fuel they consume is capable of producing.

The non-manufacturing portion of the community on hearing of the misdeeds of workers in iron and spinners of cotton may possibly congratulate themselves on being exempt from this wilful and wicked waste of their country's wealth. As in many parallel cases, no praise could be less well deserved, for if a nation has to be held responsible for national sin, no purpose to which fuel is applied will have more to answer for than the domestic fireplaces of these islands.

Let us imagine four persons, burning four candles, to be placed in an ordinary apartment, say, 20 ft. long, 15 ft. wide, and 12 ft. high, and, therefore, containing 3,600 cubic ft. According to data given by your townsman, Dr. Angus Smith, were the air of such an apartment never changed, in two hours its atmosphere would contain .317, or rather more than a quarter per cent. of carbonic acid, produced by the breathing of its occupants, and by the combustion of the candles. To avoid the unwholesome pollution which would ensue from not changing the atmosphere, suppose the entire contents of the apartment had to be renewed five times in every hour, and that, as an extreme case, this quantity of air, viz., 18,000 cubic ft. had to be raised in temperature 50 deg. Fahr. by means of artificial warmth. This ought to be effected with an expenditure of about 1 lb. of coal per hour, against which quantity I would ask any householder to contrast the figures he will find in his coal merchant's bills. Such a comparison would prove beyond all question that of the 20,000,000 tons of the annual produce of our collieries, used for domestic purposes, a mere fraction is beneficially utilized.

Your President, Lord Derby, in his inaugural address, suggested an inquiry into the cost of the cloud of smoke which constantly hangs over Manchester. Its solution would not be an easy matter; but I am sorry to have arrived at the conclusion, that viewed as a money question to the offenders it is a less costly one than many people appear to imagine. Of the carbon contained in coal about 20 per cent. exists in the volatile form, and it is to the imperfect combustion of this portion alone that smoke is due. It is very difficult, indeed impossible, to give even an approximation to the average amount of defective oxidation or combustion of this volatile carbon in a large town like Manchester; but speaking from the result of my own observations I deem it improbable that even so much as one-fourth of its weight escapes combustion. If so, then the loss from smoke is equivalent to something under 5 per cent. of the total weight of coal consumed.

The cost of smoke to the producer has unfortunately not hitherto been sufficient to induce him to guard with the necessary care against its occurrence, and the loss falls on society at large, which is made to pay for the visitation, in the presence of dirt-defaced buildings, and a ruined landscape. Smoke is unquestionably one of the preventable evils we have in this country to endure, and it is one of such a magnitude as to justify public attention being directed to its amelioration.

A remarkable instance of the waste of fuel, and nuisance arising from smoke, is to be found in the manufacture of coke. This operation consists in expelling the volatile constituents of coal by means of heat, which is performed in a vaulted chamber, formerly constructed with a simple opening at the top, the latter not more than 10 ft. above the level of the ground. At the present moment there is produced annually in the county of Durham alone, something like 3,000,000 tons of this charred coal, which means that out of ovens of the old form, and still frequently in actual use, the smoke from upwards of 5,250,000 tons of coal, and containing probably 20,000 tons of sulphur, in the form of acid vapors, would be distributed over the face of the country, vomited from thousands of low chimneys only 10 ft. high. This barbarous state of things is being rapidly amended in the district alluded to, but not without a struggle, and before miles upon miles of land have been changed from landscapes of great beauty to a blackened wilderness. So far as the nuisance from imperfectly-consumed gas was concerned, the remedy was simple. All that was needed was a flue and chimney of sufficient altitude to dilute the vapors with atmospheric air before they reached the ground, and yet this was resisted ostensibly because it was alleged it affected the process, but I fear, in reality, because the coke burner objected to the expense of construction. As regards waste of fuel, I estimate that upon the 3,000,000 tons of coke produced there is a loss of heat fully equal to 2,000,000 of tons of coal, a loss which, in most cases, is going on at the present day.

It frequently happens the manufacturer has to submit to what, so far as his own special operation is concerned, is an unavoidable loss of heat, arising from conditions of its evolution and the temperature at which it is escaping; but this is not the case with the coke burner. The ovens are almost invariably at the colliery, where large quantities of steam are required for raising the coal from the pit, and freeing, the mine from water. For this the waste heat of the coking process is amply intense, and speaking from my own experience, I may say that in collieries with which I am connected, there has been a saving of from 15,000 to 20,000 tons of coal per annum by connecting the engine boilers with the coke ovens.

I have thus endeavored in the very short time placed at my disposal by the Council of this Society, to select a few instances in attestation of the propriety of calling by means of an exhibition public attention to the study of an economical consumption of fuel. The researches of the mathematician have placed within the reach of every one rules for dealing with space and numbers. Your townsman, John Dalton, a name honored wherever science is revered, bequeathed to mankind an everlasting legacy in the "Atomic Chemical Theory." The mechanician and engineer cannot move a step without mathematical knowledge, and the manufacturing chemist, ignorant of atomic weights, is as a mariner on the wide ocean without a compass.

In more modern days chemists and physicists, led on by the charm which accompanies all investigation into the secrets of nature, have made us acquainted with the laws regulating combustion, the heat produced by coal in its different degrees of oxidation, the exact nature of the chemical action of many of our processes, along with the quantity of heat required for its accomplishment.

Among the latest discoveries is that which enables an engineer to state correctly the maximum moving force evolved by burning a pound of coal.

Shall it be said that they who consume coal, who are making inroads, slow, it is true, but sure, into the stock of a material upon which our commercial prosperity is founded, shall pursue their avocations as if no such knowledge as that to which I have alluded lay ready for its proper application.

To this inquiry I trust the labors of the Council of the Society for the Promotion of Scientific Industry, will afford the assurance of a direct negative.

THE HORSE-POWER OF BOILERS.

From "The Engineer."

We are happy to state that there is some ground for believing that the vague term "nominal horse-power," as applied to steam engines, is falling into disuse. The action of the Admiralty has no doubt tended to this end. For some time past, although the nominal power of engines is given in our naval returns and reports, the figures have been invariably accompanied by those which express the actual power of the engines as derived from indicator diagrams taken during the official trials of a ship. The good example thus set is being followed by many engineers; and it is not unusual nowadays for a maker to state that he cares nothing about nominal power, but that his engines will indicate such and such a power with a given pressure of steam. This is as it should be, and we venture to hope that the time is not distant when engineers will refuse to buy and sell engines by the nominal horse-power, preferring instead to give the actual dimensions of an engine in cubic capacity of cylinder per minute. We are not aware that this method of estimating horse-power has ever before been proposed. Engineers are, however, drifting towards it; and many engines are now sold by the diameter of piston, and speed in feet per minute. It is obvious, however, that the expression we have suggested is far the simplest that can be adopted, as it combines at once the velocity of piston and its diameter. Of course it may be urged that the terms are still indefinite, because the power will depend on the boiler pressure and the grade of expansion adopted. As it happens, however, that pressures and grades of expansion do not vary within very wide limits, it would be easy to adopt a standard which would suffice for all commercial purposes. For example, a very common type of engine, such as is used in our cotton factories and mills, works with a boiler pressure of 60 lbs. above the atmosphere, the cut-off taking place at one-fifth of the stroke. This represents a very good class of engine, and no difficulty would be experienced in assuming the presence of these conditions, and then expressing the power of the engine, as we have said, in terms of the cubic feet swept through by the piston per minute. Thus, if the piston of one engine sweeps through twice as much capacity as another in a minute, it is of double the power; and no account whatever need be taken of the length of stroke, diameter, or number of revolutions. We commend the idea to the attention of our readers.

Although, however, there is some prospect of a change for the better in estimating the power of engines for trade purposes, we regret that in the matter of boiler power the prospect is not so satisfactory. If questions connected with the nominal horse power of engines are unsettled and vague, those referring to the power of boilers are simply in a state of chaos. At the present moment there is absolutely no received rule for estimating the power of a boiler; that is to say, no rule generally recognized by the trade. As regards Cornish boilers, for example, some makers give 1 ft. in length for each nominal horse power, regardless of any other conditions; and thus, whether a boiler is 5 ft. in diameter or 7 ft., if it is 30 ft. long, it is a 30-horse power boiler, and so on. Double-flued Lancashire boilers are rated a little higher, 9 in. length of boiler representing a horse power. Nothing can be more vague, perhaps than this. If we turn to marine boilers, we find some makers estimating their power entirely by the grate surface; but while one maker divides his grate area by .8 and calls the result the horse power, another uses .75, and another uses .5. Thus, a boiler with 100 sq. ft. of grate surface may be called 125, 133, or 200 horse power. Others, again, neglect grate altogether and go by heating surface; and anything between 12 ft. and 25 ft. is said by different makers to represent a horse power. As for portable engines, the power of the boiler is always expressed in terms of the diameter of the cylinder! Nothing would be more difficult than to settle a dispute between the seller and buyer of a boiler concerning its horse power, if reliance were placed solely on the practice of the trade. To all intents and purposes there is no trade practice in the matter of more than the most local and limited application. It is hardly necessary to say that this position of affairs is and has been unsatisfactory; but if it was bad before, it is rendered much worse by the introduction of new boilers of the sectional type, to which not even the semblance of a trade rule can be made to apply.

The evil has been so much felt in the United States, that as far back as 1870 the Franklin Institute, a well-known scientific body, holding their meetings in Philadelphia, and taking a position somewhat between the Royal Society and the Institution of Civil Engineers in this country, appointed a committee to investigate the whole matter, and endeavor to arrive at some definite conclusion as to what should be deemed to represent a boiler horse power. The committee sent in one report on June 21, 1871, a second report on June 18, 1872, and two additional reports on November 19, 1873. These several reports have brought the labors of the committee to a conclusion, and the committee has been dissolved. After a most elaborate investigation, and an enormous correspondence with engineers all over the world, the result arrived at by the committee is that Watt's old rule, with limitations, better than any other defines the horse power of a boiler. This rule runs, as many of our readers, though probably not all, are aware, thus: 1 sq. ft. of grate surface, 1 square yard of heating surface, and half a square yard of water surface, represent a horse power; and these dimensions will suffice to evaporate 1 cubic foot of water per hour. The committee saw in a moment that under the existing conditions of boiler engineering it would be impossible to apply this rule in its integrity, because, for example, in most modern boilers much more than 9 sq. ft. of surface are allowed to each foot of grate; so it has been finally settled by the committee that the evaporation of a cubic foot of water per hour represents a horse power, and that, while on the one hand a purchaser of a 20-horse power boiler has a right to receive a boiler which will evaporate 20 cubic ft. of water per hour, so, on the other hand, a maker has fulfilled his obligations if that which he sells as a 20-horse power boiler will evaporate 20 cubic ft. of water per hour. The committee add that after all it is utterly impossible to lay down any satisfactory, or even approximately satisfactory, standard for estimating the power of a boiler, and they go on to say that, "in view of variations of capacity of the same boiler under varied conditions, the discontinuance of the term horse-power, as descriptive of the size and capacity of the boiler, would appear to be proper; and it is suggested, as preferable, that purchasers and makers should, instead, describe fully and in accurate terms the evaporative capacity of boilers proposed, and the conditions under which they are to be worked and tested, or to specify the indicated horse power to be developed in an engine under fully and exactly stipulated conditions of speed, pressure, economy and grade of expansion." We cannot help regarding this as being in one sense a very lame and impotent conclusion; perhaps unavoidable, certainly unsatisfactory. It is, of course, highly desirable that in purchasing boilers strict stipulations should be laid down as to the quantity of steam which they must supply in pounds per minute. But such a stipulation does not at all meet the real difficulty of the case. To the great majority of boiler buyers, weights of steam and water pressures, temperatures, and all such questions are so much Sanscrit. They buy a boiler where they best can—an immense trade, for example, is done in second-hand boilers—and the only means they have of explaining what they want is to state the horse-power of the boiler they require. A great many boiler makers and boiler sellers, brokers, auctioners, and others, know nothing about the steam-generating powers of the boiler they sell; and in such cases the recommendations of the Franklin Institute Committee would be absolutely a dead letter. Something equivalent to the phrase "nominal horse power" is essentially necessary in the boiler trade; and if some definite idea were attached to the words, and accepted generally throughout Great Britain, all that is really required would be done. It has been proved that it is quite out of the question to attempt to lay down any rule applicable to all classes and varieties of boilers; but it is not difficult to divide boilers into groups, and practice is so far identical as regards each group, that it is quite possible to establish a satisfactory standard of power for each.

We suggest, then, the adoption of something like the following scheme as a solution of the difficulty:—Let all boilers be divided into four classes or groups. The first will include Cornish, double-flued, and plain cylindrical generators; the second will include the "box" type of marine boiler; the third will be the cylindrical high-pressure marine boiler; and the fourth will be the portable boiler. Locomotives we exclude altogether, as those engines are never bought and sold by the horse-power. In the first group let 10 sq. ft. of heating surface be held to represent 1-horse power. This is very nearly Watt's rule, but it supplies a more convenient coefficient than Watt's, as it is only necessary to ascertain the whole heating surface, no matter how obtained—by Galloway tubes, for example—and to cut off the last figure; the remainder shows the commercial horse-power. As regards the second group, low-pressure marine boilers, let 20 sq. ft. of heating surface be taken to represent 1-horse power; this is closely in accordance with trade practice at present. There is more difficulty in settling the power of high-pressure marine boilers. These are almost invariably deficient in grate surface, and the tube surface is much larger in them as a rule, as compared with the grate area, than it is in "box" boilers. The grate area is, however, after all, too important a factor to leave out altogether, and therefore it will be proper to bear in mind that each foot of surface is not so efficient in the high-pressure as in the low-pressure boiler, although these high-pressure boilers are the more economical of the two. All things considered, we believe it will be fair to take 30 sq. ft. of high-pressure cylindrical marine boiler as representing a commercial horse power. As to the last group, portable engine boilers, this may be made to include as well a large number of stationary boilers which are of the portable engine type, with large tubes. To this group we should assign 15 sq. ft. of surface as representing a horse power.

We do not suppose that the standards we have thus laid down will meet the wishes of every engineer, and we wish it to be understood that we do not put them forward as being more than approximately the best that can be adopted. We believe, indeed, that the entire subject ought to be discussed fully by engineers and boiler makers in our correspondence columns, and thus an expression of opinion might be elicited which would go far to settle the question. Of the importance of the points at issue there can be no dispute; and we feel assured that it requires but a little exertion and discussion on the part of boiler makers to place the purchase and sale of steam generators on a satisfactory footing. It is not probable that any decision which may be arrived at will give universal satisfaction. But we rest convinced that if a few eminent firms would agree among themselves as to what the words "nominal boiler horse power" mean, others would follow suit, and, perforce, accept a decision which would quickly be regarded as legally binding, because representing trade practice of the highest class.

OUR KNOWLEDGE OF HYDRAULICS.

From "The Builder."

A knowledge of the science of hydraulics is one of the most difficult and important of all the acquisitions of the engineer. The subject is one of which the delicacy is equal to the importance. It lends itself, on the one hand, to the most profound mathematical investigation; while, on the other hand, it often presses for the most rough-and-ready solution in daily practice. It is the key of sanitary engineering. The supply and flow of our rivers, the amount of rainfall, and (what is of far more moment than the actual descent) the quantity of that fall that betakes itself to the ascertainable water-way of river channels, are matters of vital importance to be known and understood.

Let none of our readers think that we are speaking on theoretic grounds alone. It is from no wish to insist on the mathematical form of the problem, and to undervalue the importance of the practical part, that we now write. We will mention one fact, which is more eloquent than any argument we can frame, in stating that we have yet our A, B, C to learn as to the hydraulic system of this country. The quantity of water that is annually drawn from the Thames by the five great water companies that supply London from that source, is pretty accurately known. Is it credible that there should be a doubt, not in the minds of those unacquainted with engineering subjects, but in the minds of those who write to instruct the public upon them, or who offer evidence before commissions of inquiry, as to the proportion of the total volume of the river borne by the quantity of water thus abstracted? Yet such is the case, and that to an extent that is perfectly wild. It might be tedious to give all the details which lie before us as we write; but the upshot is, that while the eighty millions of tons of water that are thus abstracted form, according to the Report of the Royal Commission of 1869, only about 1-25th part of all that falls over Teddington weir, they amount, according to another statement, to fully an eighth part of the quantity that so falls when the Thames is at its lowest. So prodigious a discrepancy is enough to show that the subject of river hydraulics is not one as to which the engineers of Great Britain have any great reason to feel satisfied with their acquaintance.

In fact, we have far better opportunities in this country for studying tidal phenomena than for mastering those of rivers. Our coasts are swept by tides of almost every variety known to observation. About Yarmouth, and the eastern part of Norfolk, they are so feeble as to some extent to resemble those of the Mediterranean. Yet in the estuary of the Thames they attain a considerable height. Again, in the Wey, at Chepstow, occurs a tide higher than is known to rise on any shore whatever, except it be that of the Bay of Fundy. From that formidable and destructive phenomenon which is known as the surf, and which, on the Madras coast, rushing up in a single and unexpected wave from the sea, inflicts such sudden damage, we are for the most part happily free. It is within our knowledge that, now some years ago, when tenders were asked for for the construction of an iron pier on the Madras coast, it was required by the specification that three engineers, each competent, in case of need, to take charge of the erection, should come out together with the ironwork. The main reason for that unusual demand was said to be the risk, not so much of the climate, as of the carrying off the directing officer by the surf. But even in this aspect the shores of Great Britain are not without their occasional phenomena of magnitude. Although of rare occurrence, yet one of the most striking of estuary movements is sometimes to be observed in the Severn. When south-westerly winds coincide with equinoctial spring tides, a *flôt*, or bore, such as that which occurs on the Seine, is visible below Gloucester, on the Severn. And the stone pier that runs out near the castle cliff at Scarborough was swept, a few years ago, by an unexpected wave from the north, that carried off a gentleman, whose death produced much sensation at the time.

The great points which are of value for the acquisition of positive knowledge as to river phenomena, are less ascertainable on our island. For, although we are accustomed to regard the Thames, Severn, and other sister streams as large rivers, such is not their position in regard to the river systems of the world. The area of our island, if its whole water-shed were emptied by one large funnel, is small compared with the collecting grounds of some of the vast rivers of the New World; to say nothing of that which keeps up the African marvel, the perennial flow of the Nile; while at the same time supplying the no less mighty stream of the Congo. Over the smaller area, again, the rainfall is insignificant, compared with that which deluges the Equatorial mountains. At one spot, indeed, which is known by the quaint name of Styehead Pass, a register of rainfall gives an annual depth that is almost tropical. But our physical maps divide the surface of the country into districts receiving from 25 in. to 45 in. of annual rainfall. Of this comparatively small amount of water, which runs by three versants to the sea, and which thus nowhere accumulates in one river outlet of a length of more than some 200 miles, the proportion which actually thus discharges itself is, at this moment, unmeasured and unknown.

Great changes of condition are among the elements of physical observation which are the most precious to the observer. But no less important are the phenomena of permanence and of durability. There is yet another element which, in hydraulics, is of extreme importance, and that is magnitude. The volume of a river is a subject of extreme importance. From an accurate study of a really great river it is possible that facts may be ascertained, which will throw light on obscure phenomena in the behavior of smaller rivers. To reverse the method is less satisfactory. And when, as is but too much the case, we commence the study of hydraulics on yet smaller proportions; when from the flow of water through pipes, or narrow artificial channels, we construct formulæ, which we afterwards apply to the movement of great masses of water, we follow an absolutely non-scientific method. Our present theories as to river hydraulics are tentative and empirical, to a degree that greatly impairs their value.

Our absence of thoroughly sound knowledge on the subject of river hydraulics is unfortunately illustrated by the opposition which is often raised to the reclamation of low-lying land from tidal waters. On the banks of the Forth, the Tay, and the Clyde, many hundreds of valuable acres have lately been added to the area of Scotland by embankments. The drainage of thousands more has thus been rendered practicable. The great obstacle to the extension of this truly national and patriotic work, has been the fear of the vague and undefined rights of the Crown to the foreshore. But this legal difficulty would, there is good reason to suppose, have been removed by this time, but for the fallacious arguments brought forward, to the effect that the channels of the river would be silted up if the funnel-shape of its mouth were interfered with. The very reverse is the outcome of experience. Still, we have no man, and no work, of sufficiently eminent authority, to lay down, on this subject, the law, which is not that of Parliament, but that of nature.

We have repeatedly called attention, in these columns, to the general problem of the right distribution of the most precious gift of Providence, next to the light of the blessed sun itself, to this country,—an abundant and neglected rainfall. Very lately a writer, dating from beyond the Forth, has been attacking in detail that which we have attacked in mass. The valley of the Blackwater is the spot to which attention is thus called, by one who is acquainted with its nature and condition. Twenty thousand acres in that valley, which are now worth about 15s. an acre of rent, would be worth £3 per acre if drained. As it is, one half of this area is submerged by every flood; and the other half has the water so dammed back upon it that all the ditches are stagnant during winter, and the herbage is all sour accordingly. During the summer, this land will scarcely carry cattle; and the hay made from it is only fit for half-starved, hungry beasts; while the inhabitants live in cottages where the water is often level with the floor.

For some forty miles above its junction with the Thames, the valley of the Kennet is liable to very similar remarks. Reeds and rushes grow, owing to the barbarous method of flooding, or rather swamping, the undrained meadow lands, where the richest grass would repay ordinary care. The waste of productive power in what might be land of extraordinary fertility, entirely independent of drainage from a season of drought, is positively lamentable. The whole cost of deepening and straightening the river, in the case of the Blackwater, it is estimated, would be recouped by the increased production within five years. We cannot doubt that the same would be the case with regard to the valley of the Kennet. For men who wish to make money, not by wild speculation, but by the profits of assured industry, invested on English soil, these valleys offer the means with absolute certitude.

We have given an instance, in a variation of more than 200 per cent., in professional estimates of the volume of the Thames, of the backward state of our practical knowledge of hydraulics. If we look at the rules and formulæ, as given by our best text-books, we shall see that they do not advance the student beyond guess work. "To find the volume of flow of a stream," we are told to "multiply the mean velocity by the sectional area." That, of course, is irreproachable. But how to find the mean velocity? That question is one that demands a series of well-connected and perfectly-performed experiments; experiments that can only be satisfactorily carried out by special instruments, and with the utmost care. But so far from this important truth being indicated in our text-books, we can there only find theoretical rules as to the "relation between head and velocity." This is expressed in a formula, which we suppose that we may regard as the basis of our actual river engineering. We find no reference to observation in the formula.* The force of gravity expressed by the head of water, is all that is brought forward. When the "factor of resistance" is introduced into the equation, the same purely theoretical mode of treatment is still continued. But this is not the worst. We find positively erroneous statements added. We have a rule, thus conceived, "In a stream like a river channel, the ratio of the mean velocity to the greatest velocity (which occurs at the middle of the stream) is nearly equal to the greatest velocity plus 7.71 ft. per second, divided by the greatest velocity plus 10.28 ft. per second." Now it is not only the empirical and utterly unscientific vagueness of this statement which we condemn. The few words within the parenthesis contain just one of those mischievous assumptions which are the parents and propagators of error. Nothing can be more wide of the mark. The velocity may be greater at the centre of the stream than elsewhere. But, on the other hand, it may not. The actual fact is, that the inclination of the surface of a river being given, its velocity is a function of its depth. So far as we are aware, we shall exhaust all our English text-books on the subject without finding this primary element of calculation anywhere distinctly intimated.

We are indebted to a member of the Institute of Civil Engineers of Vienna, Mr. J. J. Révy, for a great amount of practical light on a subject of so much interest to the sanitary and to the agricultural interests of this country. It is not as a matter of theory that Mr. Révy criticises our hydraulic formulæ. Nothing can be more modest; but at the same time nothing can be more thorough, than are the observations of this very careful engineer. It seems that Mr. Révy has been employed by the Government of the Argentine Republic to report on the estuary of the Plata, and the gigantic rivers which pour into it. Of these, the mother stream, the Parana, is, with the exception of the Amazon, the largest in the world. In 24 hours it sends down to the sea a volume of water equal to that discharged by the Thames (as at present estimated) during an entire year. It soon became evident that theoretic formulæ were absolutely nowhere in presence of these circulating seas of water. No basis of calculation was to be arrived at from estimates of velocity due to head. Nay, more, it became apparent that it was no simple matter to ascertain what that head actually was. We are accustomed to place considerable reliance on the spirit-level. With a good instrument, in good repair and adjustment, a calm day, an experienced and careful observer, and the rigid use of equi-distant back and fore sets, considerable accuracy may be thus attained. We should say, as far as our own practice bears upon the subject, that a level thus obtained may be relied on to about three-hundredths of a foot per mile. That would be considered a fair check. In setting out masonry by the spririt-level, perhaps a greater degree of accuracy may be attained; but the process is slow and tedious. We can remember an instance in the case of the setting out of the retaining walls betwen Camden-town and Euston-square, on the line of what was then called the London & Birmingham Railway, in which, although unusual care was taken, and the levels were read on iron wedges driven into the joints of the brickwork, day after day they would come three-hundredths of a foot wrong! The fact was extremely perplexing. Every endeavor was made by careful adjustment of instrument, and laborious detail of observation, to detect the source of error; but day after day it recurred. At last it caught the attention that the error was always of the same amount, and always in the same direction. This led to a renewed investigation. The result of this was, that the error was not cumulative. Although it recurred in the work every day, it did not augment. This led to the running of a new series of levels along the plinths of all the pilasters that were completed. The fall was exact in every instance. At last, by reference to a bench mark fixed for the purpose, it became evident whence the difficulty arose. It was due to nothing but the expansion of the concrete on which the wall was built! The levels were always given at the same period of the growth of the wall; that is to say, on its arrival at the plinth. The same degrees of expansion in equal thicknesses of concrete had thus always taken place. This was, as it turned out, at once a beautiful proof of accuracy of work, and a valuable note as to the behavior of concrete. But it is an instance of the mode in which, with all the appliances of modern civilization, we may approach the limit of instrumental accuracy

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* The formulæ are $h = \frac{v^2}{64}$ and $v = 8.025\sqrt{h}$.

in the use of the spirit-level. Over long marshy districts, jungle, swamp, or fen country, such as we find in Norfolk, the level becomes almost useless. We do far better to trust to a natural water-level, if this is shown, by the absence of current, to exist, than to rely on the use of the spirit-level, even in many parts of England. By the side of the vast rivers of America, or of Africa, such levelling is altogether out of the question.

We have spoken of three-hundredths of a foot per mile as being as fair an approach to accuracy as we can expect under ordinary circumstances. In our fen districts the minimum fall allowed for the water-channels is 4 in. per mile. The wind will stop the flow of water through the dykes, if propelled by a less head than that. The constant service of windmills, pumping day and night, and the entire system of polders, dykes, sluices, and outfall, are calculated on that gradient. Its ascertainment is, as we see, within the limit of instrumental accuracy.

Now the surface inclination of the La Plata River happens, by a remarkable coincidence, to fall within a very minute fraction in that very limit of instrumental accuracy. Three-hundredths of a foot is the same thing as thirty-six-hundredths of an inch. The surface inclination of the La Plata was ascertained by Mr. Révy to vary from .342 to .444 in. per mile, and with a gradient that in our fen districts would not overcome the opposing force of a moderate wind, the mighty volume of that great river has a surface velocity of more than 100 ft. per minute.

Into the further investigation of this great problem our limits will not allow us now to enter. But we hope that we have said enough to call the attention of all those who take interest in hydraulic knowledge to the fact, that a problem exists, and that its solution, if attained, is not to be found in our text-books, or expounded by our professors. It is no vagary of nature that impels the mighty stream of the Plata down an incline almost imperceptible to our instruments, and which our fen-draining engineers might afford to neglect. In fact, they might neglect it with safety. The cause of the apparent anomaly lies in the great depth of the American river,—a depth of 24 ft. at the section observed. To this depth is due the velocity of the current, and the constant displacement of an enormous mass of water under the solicitation of a minute gravitating force that would prove inadequate to overcome resistance in a shallower channel.

We cannot give, in a few words, a more distinct proof of the importance of regarding depth of channel as a function of the velocity of rivers; and the fact that this function is entirely disregarded by our formulæ may perhaps account for the fact, that one hydraulic authority (as things go at present) tells us that the flow of the Thames is considerably more than double of that at which it is stated by another engineer.

PUBLIC WORKS IN INDIA.

From "The Building News."

The Food Crisis in British India has revived the question of Public Works in that region; but a great deal of misapprehension appears to exist upon the point. These undertakings are not to be regarded as pretexts for giving employment to thousands who might otherwise be without wages; they are intended to make the country what it should be—fertile, available for all purposes of commerce, and open to the genius of modern industry. Anciently, the wild splendor of the Delhi dynasty, and even preceding them, the Hindoo monarchs engaged myriads of cultured craftsmen in erecting tombs which were literally palaces of the dead, and left such memorials as few other ages or nations can equal; yet these were, generally, the monuments of a foreign art, and little more than the drudgery of enterprise was left to the native race. Recently, however, a great change has occurred. The toil and skill once devoted only to tanks and temples, are given to constructions more useful and more beneficial to the land. In British India, perhaps more than in any other territory of the globe, China excepted, the fertility of the soil depends upon the adroitness of the husbandman; even this, without the help of the engineer, is comparatively useless; for where is the reason of growing crops amid which a spear-bearing horseman may ride without being perceived, unless there exist means of transporting the surplus produce by railroad, river, or canal? India wants railways, canals, the improvement of rivers, bridges, aqueducts, and highways, which are being, as a fact, very slowly supplied to her. No doubt, a large extension has taken place; there is a line direct from Madras to Malabar; there is another, with breaks, however, at the ghauts, from Bombay to Bhosal; and, taken altogether, there may be 5,000 miles in working order. Still, these additions, chiefly military in their objects, do not meet the practical wants of that enormous population, principally resident in villages. One grand necessity is of roads, along which wheeled carts can conveniently travel. Many tramways have been constructed, against which a majority of the people have hitherto exhibited a prejudice; yet this feeling, it may be hoped, will in the course of time, be overcome. There are many districts, however, in which the mechanical difficulty of making even a passable road seems next to insurmountable, if we are to judge from the reports of the India Office. After railways and common roads, the canals and the rivers follow, though more as main arteries than as means of domestic intercommunication. A system of navigable canals is of the utmost importance, both as regards the inland traffic, and as contributing to the irrigation of a land so frequently desolated by droughts. During the last great famine in Bengal, the Ganges Canal brought grain, in myriads of tons, to the upper provinces. It covered the land with plenty, and yet it has never paid a farthing of interest upon the original cost; it fed a million and a half of people, without encouraging either Government or any union of speculators to attempt a second similar enterprise. Still, this is not true of all the Irrigation Works in India; those in the Cauvery and Coleroon districts, for example, have more than doubled the value of the grounds they water, and which famine, since their completion, has never visited. In the basin of the Godavery, again, Colonel Arthur Cotton reclaimed from sand and thirst, by a magnificent series of Public Works, 1,200,000 acres of formerly worthless but now profitable soil. These facts should have an interest for the practical classes of the public, in all countries. Colonel Cotton built a "bar," which turned the current in a full volume over the arid neighborhood, and converted the desert into a garden. So at Kistnah; so returning for a moment to facilities of intercommunication with the Grand Trunk-road from Calcutta to Peshawur, upwards of a thousand miles in length, and with that unique bridge across the Godavery where it is most dangerous, and most liable to change its course. That river, for many years, checked the benevolent ambition of Indian governors-general and engineers. It wanted clearance in some places and obstructions in others; it required a periodical storage of waters, a supplement of canals, a succession of dams and then of still-water pools, the blasting away of huge rocks in mid-stream, wing-walls, arm-cuts, groins, and artificial banks, and the removal of shoals caused by accumulations brought down from the mountains. But nearly all this has been effected with results the most satisfactory, notwithstanding extraordinary natural obstacles. "Our quarries and sand-beds," writes the resident engineer, "are in the bed of the river," so that, in the season of floods, they were unavailable. With respect to roads and canals, we have made a surprising advance, and attention should be given to them, especially as regards the harbors upon which they open. The bridges throughout have opposed the greatest difficulties to the engineers, although the deep channels and cuttings, the incessant cross-drainage, and the steep gradients, mounted by means of a machinery peculiar to India, have been obstacles sufficiently serious. All this, however, is essential to the very existence of the population, and it has still proved inadequate under a heavy and sudden pressure. There exists in abundance what are called "wet weather," and what are called "dry weather" roads; the one during long seasons rendered impassable by dust, the other made impracticable by muddy ruts, in which a cart's wheels will disappear to the axle. Some are entirely unavailable for carriages of any description; but all are crowded with a vast and increasing traffic, either from point to point along the various routes, or converging towards the sea. The sea approaches to the hidden interior have, of late, been wonderfully improved. Thus, the new harbor of Beitkul, almost superseding that of Madras, is almost an artificial creation, although nature has sheltered it from the worst winds of that storm-beaten coast. A small breakwater, consuming about half a million tons of stone; a connection of masonry effected between two little islands outside, and a noble wharf obtained by merely blasting down the overshadowing rocks, have provided a secure and spacious haven of which Anglo-Indian engineers are justly proud. All this, however, was in association with the new canal system, because the natural rivers have, for the most part, inconveniently precipitous falls, and changes of current necessitating numberless shifts of the navigation, ferries, short land transports, where the streams become no better than swamps, and so forth. India, it must not be forgotten, suffers not less from an excess than from a want of water, and the grand object of her engineers is, of course, to regulate and distribute the supply. Thus, an important interest has been practically ruined by the influx of a sweet stream into the salt swamps of the celebrated Mogultoor Talook, where every particle of saline matter was of value. On the other hand, the Hindoo looks upon the neighboring tank as English farmers do upon the rain and sun of Heaven, and upon the construction of these mighty reservoirs a mighty genius has been exhibited. They are vast, deep, bottomed with the finest sand, embanked by solid masonry, furnished with admirable inlets and outlets, and protected almost as though they were sacred. No person is permitted to bathe in them, no fowl are suffered to swim upon their surface; they are intended solely and simply for the domestic water-jar and the fructification of the fields. Their drying-up or exhaustion would signify, in an exceptionally torrid season, starvation, pestilence, and the withering away of the people. It will be seen, then, of what vital necessity are public works in such a region, in which the monuments of former industry, however magnificent, are gradually wearing away. They are necessarily of considerable cost, no doubt; but with one or two exceptions which we have noticed, amply repay it, within a short period. Thus, the great Godavery Weir absorbed:—350,000 tons of stone for the rough stone-work, at 1s. a ton; 300,000 used in rubble and other masonry; 150,000 cubic yards in rubble masonry, the deepest part of the water; 45,000 of cut stone masonry, and quantities upon a similar scale for artificial islands, excavations, and wells. We have here a glimpse of the contrast of Asiatic, as compared with European work. The artisans are principally paid in food; that is, in rice, at the rate of a farthing the pound; they dig up a square yard of earth for the same remuneration; they drive a blast of gunpowder for three half-pence per each sixteen ounces; and yet their labors, though active and ingenious, have often brought small return to their employers. On one river, 80 miles from the sea, the engineers have had to break and blow through a dense ridge of primitive rock, capped with laterite, nearly 3,000 ft. high, and they had to work their way for 5 miles before the waters could have their free fall towards the ocean. Then we must remember that the country is a Delta, infinitely more intricate than that of Egypt, and bearing this in mind, the exceeding merit of the works constructed becomes apparent. The facing wall is 12 ft. high, of rubble masonry, built with hydraulic lime, having a level surface, 18 ft. wide, and a slope curving towards the down-stream. The whole rests on sand, the lower side, being supported on brick wells, filled with stones and clay. There are embankments in every direction, to change the course of the waters, when necessary; but without encumbering our columns with superfluous details, we may describe them as three locks; three head sluices to the channels; three sets of under sluices; the embankments carried across the island; the four Weirs, 48 ft. thick of masonry, with aprons of rough stone 30 yards in width; and great irrigating channels, the influence of which is as the periodical and beneficial rising and overflow of the flood in the Valley of the Nile. It has again and again been said that water is, in India, more precious than gold in Australia: it improves agriculture; it cheapens food by cheapening transit; it prevents a bad season from impoverishing another. In three ways the fluid stored up is used: for complete irrigation; for supplying deficiencies; and for the nurture of crops that are long in ripening. We must next take into account the state of the question as it affects the internal navigation of the country. This involves the great problem of the comparative value and importance of internal navigation and land communications, with special reference to India. Whether railways are to be substitutes for canals, or canals for rivers, are still moot points. The railway can never surpass the canal in cheapness, nor the canal the railway in speed.

Which, then, is the more important loss, that of time or of cost, in transit? When the determination of policy of Public Works in India comes to be made definite, these are considerations which will not be lost sight of.

BRASS.*

From the "London Mining Journal."

What is brass? It is perhaps not so easy to answer that question. I think we shall be justified in restricting the term brass to alloys of zinc and copper only. Antiquarians and collectors of coins frequently apply the term brass to what we should call bronze, or gun metal, an alloy of copper and tin, and this causes much confusion. It is curious to find more than 2,000 years ago, in the writings of Pliny, that the same confusion existed. Now, for example, we have pinchbeck metal, Dutch metal, Prince's metal, etc.; worse than all, we sometimes find different terms applied to the same kind of brass. The old term for brass was *latten*, as we find in ancient records, and the modern French name is *laiton*. Brass was known certainly 2,000 years ago, in the days of Pliny; for he tells us there was a kind of metal known as *ori chalcum*, which means mountain brass, and it is said to have been very much like gold in appearance. But I think there can be no doubt that the term refers to our brass, inasmuch as no one would mistake gun metal for gold—its color is quite different. With regard to the common properties of brass, it has many advantages over copper, it is harder, and will, therefore, better resist wear from friction. It is a very workable metal, can be cast perfectly, it is very malleable and ductile, can be rolled out, and then beaten out (at all events when it has a certain composition)—Dutch metal for instance, can be drawn out into fine wire, raised up by stamping. It is agreeable to look at, and much cheaper than copper. When I speak of ordinary brass, without any qualification, I shall mean brass which has a composition in round numbers of two parts of copper to one of zinc. I shall describe the ancient process of manufacturing brass, which has now, however, been generally abandoned, and I do not think there is one furnace, conducted on this process, now in this country, though I saw several in full working order in Birmingham about 30 years ago. The oxide of zinc was in all cases used, and this was mostly obtained by roasting calamine, or carbonate of zinc, hence the name of calamine brass. You will remember that zinc is obtained from this oxide by heating it with carbonaceous matter in a closed vessel. Now, to make zinc we should take some of this oxide, mix it well with charcoal powder, and add a quantity—in proper proportion—of granulated copper; the mixture is then put into large crucibles and heated strongly for several hours. The zinc vapor thus separated finds itself largely in contact with metallic copper throughout the mass; it continues with the copper and forms brass. The point to be attended to is not to raise the temperature so high as to melt the copper, or that metal would form a layer at the bottom of the crucible, and our object is to keep the copper as much as possible in contact with the zinc. The furnace used is very simply constructed, merely consisting of an oven-shaped building of fire-brick; there are no bars, but a plate of iron (protected with fire-clay) pierced with holes for admission of air, and other larger holes (one in the centre, and seven or eight at equal distances round the plate), in which the crucibles are set. In the top of the furnace is inserted a cast-iron collar, and over that place a cover of cast-iron, which serves as a damper to regulate the temperature; there is no chimney. There are several of these furnaces built in a row, and enclosing them all is built a large kiln, like those we see in modern glass-houses. The furnaces are built nearly on a level with the ground, but there is an underground passage to each of them for the removal of ashes, etc. When the furnace is in working order the charge is introduced into the crucibles, and they are put in their places; the fuel is introduced gradually, and worked down and between the pots, the object being to keep up a uniform temperature. After a lapse of several hours the furnace will have done

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* Abstract of Dr. Percy's Lecture on Metals before Royal School of Mines.

its work. We then take out the central pot, and shake it well to get the molten metal to the bottom; it occupies but a small space compared with that occupied by the charge. Each of the other pots are taken in succession, and after shaking, the contents are emptied into the centre pot, and by this means we get at the end of the process, a crucible full of brass which is then cast into ingot moulds, which in former times were made of stone. This calamine brass had a great reputation, it was in high repute for buttons, for wire drawing, and especially for wire intended for paper-marker's gauze. I do not see why this brass should be so much better than that made from good copper and zinc in modern times, and I do not think it was. A few days ago we submitted to a vigorous analysis a specimen of this brass, which I obtained some years ago from Birmingham, and it showed—

Copper	60.67
Zinc	34.23
Lead	3.61
Tin	0.17
Iron	0.77
Nickel, cobalt	Traces
Total	99.45

The most remarkable feature is the large percentage of lead; as a rule, I may say the more free the brass is from lead the better it is. The brass is now made by adding spelter to the copper, previously heated to a certain degree. It is made on a very large scale in reverberatory furnaces, and there is some loss due to the volatilization of the zinc. Here is a simple experiment: let anyone take one of the old pennies, or a piece of copper, take a crucible, and put a small piece of spelter at the bottom, then on that some charcoal or fire-brick, then the disk of copper, and cover all with charcoal; heat strongly, but not too high; a coating of brass will be formed on the copper penetrating deeper the longer the process is continued; some of the Nuremberg brass is supposed to have been produced by a process of this kind.

Among the varieties of brass is one known as Muntz's metal, intended for sheathing ships. This metal, now so largely employed, is nothing more than brass, consisting of 38 per cent. by weight of spelter, and 62 per cent. of copper. The late Mr. Muntz took out a patent for it, and recommended the proportions of the metals to be used as 40 and 60, but it has been found that they are not the best proportions; it is better not to have so much spelter, as the metal is then not so liable to become crumbly. It can be rolled at a red heat, but if cooled down to a certain degree it is no longer capable of being rolled; cooled still lower, it again becomes malleable. Here is a curious fact about it; a patent was granted to Mr. Collins in 1821 nearly identical with that granted to Muntz; it was the same thing, recommended in nearly the same proportions for the same purposes, and stated to possess the same qualities. I do not now wish to get into any argument about patents, but I do say that while in the records of the Patent Office such a patent as that of Collins was written, although it might never have been brought into practice, still another patent, to all intents and purposes identical, ought not to have been granted. To show the varieties of composition in brass, here are the results of analyses of several specimens of commercial brass obtained for me by a friend; the percentage of copper in them being—No. 1, 59.59; No. 2, 63.22; No. 3, 91.44; No. 4, 71.2; No. 5, 64.85; No. 8, 75; No. 9, 72.64. If we take copper and zinc in inverse proportion—two of zinc to one of copper—we shall get a metal totally unlike zinc, very brittle, white, and quite valueless. Some time ago there was a question about cleaning some of the metal statues in Westminster Abbey, and I recommended it should be done with ammonia, something which would not corrode the metal. I thought the metal might be brass, but I found I was mistaken; here is the exact composition of the metal, the result of an analysis which has not yet been published—

Copper	83.3
Tin	1.52
Zinc	14.47
Lead	0.17
Iron	0 53
Sulphur, silver, gold	Traces.

It is substantially a brass rich in copper, the gold is probably derived from the gilding, the gilding being attached in the manner technically known as water gilding.

Another variety of brass is Dutch metal, which contains a very large percentage of copper; it is rolled out into thin leaf, then beaten out, so as to reduce it to somewhere about 1-32,000 of an inch. Then we have what are known as brass foils, sometimes most beautiful things; it requires a first-rate quality of brass, containing a good deal of copper to be able to be rolled out thin. Jewellers sometimes employ them, I think I may say not unfrequently. A very short time ago a lady showed me what she thought was a very fine amethyst, but I soon saw that it was only quartz with a piece of foil at the back. And those cheap chains too which we see so commonly now, have a core consisting of brass and gold, about eight parts of brass with a gilding of a thin film of gold. They are made by machinery, and are apt to become brittle in the course of wear.

In the ordinary process of pressing or stamping brass, as in making curtain rings, you cannot raise the surface by one blow, it requires a succession of blows. This, however, would make it brittle if it were not prevented by annealing the metal from time to time. In the process of annealing it becomes coated with a black scale which can be detached by means of aquafortis. The process of "dead dipping," to obtain a dull surface, is conducted by dipping the annealed metal into aquafortis (one part of aquafortis to four of water) till the black scale rubs off easily; then after washing in water it is dipped into acid of double the strength; this acid will attack the metal and form a green layer on the surface which really consists of bubbles of gas. When it is well coated it is taken out and washed and rubbed with cold saw-dust, and without removing the adhering saw-dust is plunged into the strongest acid. It is taken out of this almost immediately, and washed in water containing cream of tartar dissolved in it, and lastly it is placed in hot saw-dust.

THE VIENNA DOME.

From "The Building News" and "The Architect."

At the general meeting of the Institute of British Architects, Mr. J. Scott Russell, F. R. S., read a highly interesting paper on the construction of the central dome of the Vienna Exhibition Building. Mr. Russell, in his prefatory remarks said, all that he, as a professional engineer, could venture to do, was to submit for consideration those engineering principles and mechanical expedients which he thought might possibly be of service to the architectural profession in those great works which they and their successors would be called upon to undertake in the architecture of the future. His own special work in connection with the Exhibition building at Vienna was the great central iron dome. He felt it his agreeable duty in laying before a meeting of the architects of England a description of this building. From the beginning of it to the end he was deeply indebted to members of their profession for kindly help and cordial co-operation. The designs were all drawn for him by Mr. John Crace, the worthy son of a father who had long before acted a distinguished part in beautifying the two palaces of our own Exhibitions. The architectural features and decorations of the dome, as now executed, were the work of M. Hasenauer, who, at an early age, had evinced high distinction, and who inherited the traditions and talents of their profession from his distinguished father. Passing to a general description of the conic dome at Vienna, Mr. Russell stated that it was, he believed, the largest vaulted roof in the world. It covered nine times the ground of the dome of St. Paul's, eight times the area of the dome of St. Peter's, and seven times the area of the dome of St. Sophia at Constantinople. It was 360 ft. in diameter, and was 1,080 ft. round. It stood on a ring of 30 columns, 36 ft. apart, all round the circumference. Within this ring of columns there was no support. The upper dome, 100 ft. in circumference, admitted light by a series of windows, 40 ft. high and 10 ft. wide, between 30 columns which carried the upper dome. The slope of the cone was 30 deg.; the length of the slope on all sides was 200 ft. The roof was formed of 360 iron plates, tapering uniformly upwards from the circumference to the apex of the cone. They were riveted like the plates of a ship, each row of plates covered 1 deg. of the circle, each bottom plate was 1 yard wide between the lines of rivets, and 1 metre wide over the lap; each of the 30 columns carried an arch and an upper gallery all round the inside. These columns were 80 ft. high. The heights of the whole, in round numbers, were: columns, 80 ft.; cones, 100 ft.; windows, 40 ft.; lantern and crown, 60 ft.;

or 280 ft. from floor to crown, besides foundations of 12 to 20 ft. This conic dome roof had no visible external wall; it was surrounded by a circular ring building which consisted of the great central nave of the longitudinal axis of the main building, carried circular-wise round the cone, and forming, as it were, a circular aisle or series of side chapels all round about it. The conic roof, therefore, as seen from the exterior, crowned the large lower buildings by which it was surrounded, and seemed merely to grow out of them, and to group them round it into one whole, of which it was the centre. The circular ring or nave or arcade was 40 ft. wide by 80 ft. high, carried on a second ring of outer slender columns, and opening out into four enclosed courts or gardens, by large semi-circular windows and many doors. This arcade extended the circle of the central building to 440 ft. diameter, and it had the great convenience of forming a workman's communication, through the entire length and breadth of the building, with all the main entrances, without disturbing the central area of the great dome.

Mr. Russell then proceeded to consider the mechanical principles of conic-dome structures. The result of the investigation of the question on which he had been occupied some 30 years was shortly this:—That a certain conic form developed the strength of the modern material of wrought iron, on a large scale of structure, so as to attain the maximun possible of strength, economy, and endurance. Having discussed at considerable length the nature of the material and the modes of applying it, he proceeded to describe the principles of construction. The first principle, he said, was unity without antagonism. Lever roofs and trussed roofs were mere modifications of ingenious waste, in the ways in which they had been generally used. The question he now submitted was whether this double waste might not be avoided. In his opinion it was avoided in his conical roof. He thought every atom of iron in that roof did its own work only. No particle did work of antagonism. In short, it was a congregation of atoms working together for the common support, without counteractive disagreement, or waste of strength, or means, or work.

The second principle was wise distribution of structural load, and especially of that heavy load of its own material on a large scale. This principle, Mr. Russell remarked, found its happiest illustration in the cone, inasmuch as that form gave an absolute maximum of sustaining-power when on a large scale. This principle ruled the structure. The third principle was cooperation of independent parts, and perhaps it was the most important of the three, viz., that in every large structure every part of the whole should be ready and able to render assistance to every other part in the performance of its duty or in the case of imminent danger. This principle, Mr. Russell said, was rarely well carried out, or recognized at its full value. In illustrating this principle he premised that the antagonist principle of independent action of parts was a tradition of both the engineering and the architectural profession. One of the most beautiful scaffoldings he ever saw was made thus for the building of a large elliptic arch:—The whole of the centring sprung from two points; to every small portion of the arch went two long beams from the two springing centres. The pair met, and they, too, sustained one stone, or one group. A second pair, starting still from the same centres, sustained a second group, and so on, till perhaps some 50 independent pairs carried the whole arch. This had the great advantage that the giving way of one pair did no harm to any other pair; it was the principle of perfect independence carried out in timber struts. In the same manner they might have seen iron bridges of the nature of iron suspension-bridges, where, instead of the single centring chain, successive points of the bridge platform were carried by pairs of ties going straight to the summits of the two piers, and thus suspending their portions independently, so that weight on one side should not affect the others.

Treating of the nature of the iron cone, Mr. Russell considered: 1st, the crushing strain, on which he remarked that an iron cone might be examined and tested in two ways. It might be exposed to pressure from within, on the hollow side, or to pressure from without, on the round side. He had never seen a formula which explained and predicted the result either way. To understand his conic roof, Mr. Russell asked his audience to fancy a ring or cylinder of wrought-iron plate homogeneously riveted together into one upright plate 200 ft. high, and 360 yards round, and 1 in. thick. It would take a height of 224 yards to bring a weight of one ton over each inch of ring. The maximum strain possible on the lowest heaviest strained part of that ring was one ton on the square inch, say one-fifth, one-tenth, or one-twentieth of the safe or yielding, or breaking strain, therefore perfectly safe, and far within the widest practical margin. But 224 yards high for one ton of strain was far beyond his wants; he only wanted for his use less than a third part of that strain. He took a ring exactly 200 ft. high, strained therefore to less than one-third of a ton per inch; and he asked them to conceive clearly this ring resting on a smooth, flat, level base. He next asked them to follow him while he cut this cylinder in pieces—[Mr. Russell illustrated his views by diagrams on the black-board]—but leaving all the pieces in their places. He now cut the cylinder vertically into couples of triangles, one upright triangle, and an inverted triangle. He now removed all the inverted triangles, and left all the others standing upright in a ring as before, points up. He had taken away half the whole of the iron. He next inclined all these angles inwards towards each other, and they all then touched each other along the edge from heel to point. With the triangles lying in that shape and perfectly soldered in all the joints and fused by electricity, his cone was complete. The conclusion at which he arrived was, that in this state the matter of the cone was nowhere more or less strained than where it had not as yet become a cone and was the original upright cylinder; in other words, the strain on the cone was everywhere less than one-third of a ton per square inch. This was the specialty of the cone looked at as a self-sustaining roof structure, and in the matter of further economy of material he diminished the thickness of the plate uniformly towards the top, and when he had done this, only one-third of the whole material of the cylinder remained in the cone; and the maximum strain was still everywhere less than one-third of a ton to the inch.

On the subject of the tearing strain, Mr. Russell remarked it was the strain that architects most feared in roofs and domes which stretched or tore asunder the supporting walls, buttresses, arches, or ties. He closely traced the changes in the shape of the cone as it was conceived to be flattened out, from which he deduced that in correct proportion as the web narrowed did the quantity of stretch diminish. Thus, there was neither waste, defect, nor antagonism; the whole cone being in uniform tension from top to bottom, and all round. Supposing a uniform pressure of water, or a uniform fall of snow, to press down the cone top, and press out the cone base, it would meet everywhere a uniform tension of iron ring opposed to it. They thus saw that the whole cone was a series of straight-lined tapering bars, starting from a circle and meeting in a point, all of them in compression endways by their own crushing weight. They saw that at the same moment the whole cone was a series of circular hoops, increasing in thickness as in diameter, and carrying a strain proportional to the size and strength of each hoop, and increasing uniformly from top to bottom in size, in strain, in thickness, and in strength. Having treated of the subjects of the combined strains and conic skeletons, Mr. Russell remarked with regard to the practical application of the cone at Vienna, that as all structures are not perfectly adapted to all purposes, it was manifestly the duty of the architect and engineer to use each to the end it served best. Practical duty, he said, was a compromise between what one would like to do and what one had got to do. For some such aim he had been willing and ready to use a mixed structure of continuous cone and detached skeleton on large buildings. This Vienna cone was such a compromise; he claimed for it the merit of a continuous cone combined with convenience of a skeleton one.

Mr. Russell then dwelt at considerable length on the columns, walls, foundations, and accessories of the Exhibition building, which our space will not allow us to enter into; after which he proceeded to show how he brought all the strength of the cone to bear upon the columns so as to give them and itself perfect stability independent of bad foundations, shaking earthquakes, and shaking hurricanes. This cone, he said, was so contrived that if they knocked away the foundation of a column the cone would support the column in its place, and the column would support the arches that sprung from it, and the outer roof that hung from it, even when the foot of the column hung in air. The cone was sufficiently strong to carry even two or three adjacent columns with their foundations fallen away. It was so contrived that if by an earthquake the foundations were moved horizontally, the columns would not follow them, but would maintain their upright positions in their correct places under the dome. If a hurricane could be conceived strong enough to shift bodily along out of place the whole 4,000 tons of dome, the columns would shift place with the dome, and carry it as secure as now in the right place. The secret of this quality, Mr. Russell remarked, consisted in a principle he had not yet adverted to. The characteristic of a homogeneous cone was, that its whole surface consisted in a continuous series of parabolic chains or approximate catenaries in places parallel with the slope of the cone. These parabolic catenaries had the quality that they connected the summit of each and every column with the whole of the opposite, as well as with the adjacent, side of the cone. Each column was, therefore, held in place by the equivalent of a countless number of chains ending in the summit of the column, and pressing with a uniform, even-spread, gentle pressure on the skin of the cone on one side, and also on the opposite place. Further, each vertical section of the whole conic surface was a hyperbola, approximating closely to the inverted catenary, or catenarian arch. If, therefore, they knocked away one, two, or three columns, or their foundations, the mutilated cone still stood upright on all the other columns, standing on a series of catenary arches extending across the whole skin of the dome to the surviving columns, and supporting the roof by catenary equilibrated pressure. The Vienna conical roof, therefore, contained within it strength enough to resist all the strains which could fall upon its supports and connections, and that strength communicated to them through the best possible ways. To utilize this strength one more condition was necessary, that was the perfect unity of the superior structure or roof with the inferior structure or supports. In common buildings the supports, columns, arches, and walls found their strength in broad and deep foundations, whence they carried stability up to the roof. In his building, Mr. Russell remarked, all the stability was derived from the roof, and was given off into the supports by a connection to which he would direct the attention of the audience. The roof rested on thirty, or say thirty-two columns, for there were two small arches at the main entrance. These thirty main columns were neither square nor round. They were 10 ft. through one way, 4 ft. through the other way, and 80 ft. high. They were of the same material as the cone itself, combined in the same proportions, and united in the same way. They were in structure, though not in shape, part of the cone. Mr. Russell then proceeded to explain the reasons for the position and proportions of the columns, and passed on to notice the construction of the foundations, which, he stated, were mere slabs of concrete, which rested on the alluvium of the Danube, and prevented the weight of the dome from sinking down into it. The columns spreading out above, by ribs and rings, over the surface of the cone, might be said to grow downwards from spreading roots above, and merely rested on the ground, as a lame man's crutches, or as the legs of a table on a smooth floor. Their strength came from above, not from below. They lent their strength to serve the strain of all above them, and they got in return the strength and strain of all above them to maintain their position below. No parts could fall unless all else fell along with it. In conclusion, on this head of the subject, Mr. Russell remarked that the cone would stand after it was pierced all over, after its outer and inner rings were cut through, after the outer chain of the cone itself was severed. Indeed, he said, after it was severed into thirty detached fragments, it would stand. Only complete disintegration could bring it down. Indeed, it would cost more time and labor to cut it to pieces than to build it in place.

The remainder of the paper, which was of great length, was devoted to highly interesting remarks upon the history and practical execution of the Vienna building, from which we gather that the general plan, aim, and design of the Great Exhibition in Vienna having been determined in the highest quarters, his Excellency Baron Schwartz Von Senborn, who was appointed sole Imperial Commissioner, was generally regarded as the one man in all Austria best fitted for the task. The general design and aim of the building as a whole was the idea of Baron Schwartz, or those above him. From a variety of considerations, the building required to be of a different character to that of any previous Exhibition in England, or other parts of Europe. The large entrance of the Oriental element amongst the exhibiting nations rendered European plans of classification impracticable, and decided the adoption of the classification of the Exhibition on a principle purely geographical. Mr. Russell then entered into the history of the origin of his large iron dome, and stated that he designed it with a view to the Exhibition of 1851, having previous to that year discovered the peculiar qualities of the conic form with relation to large buildings of modern iron. Circumstances, however, prevented his plan from being carried out; but when in the summer of 1871, Baron Schwartz visited him in England and explained to him his views of his general plan of the group of separate buildings, he (Mr. Russell) was quite prepared with data for him as to the size, character, and cost of a great central cone.

The considerations which settled the size of the Vienna dome were mainly those of cost. It was decided that the central structure, and as much of the surrounding buildings as should be capable of permanent utilization, should be permanent. Mr. Russell then proceeded to describe the manner in which he arrived at the best mode of adapting this large cone to the central position it was to occupy in the surrounding groups of parallelogramic buildings, after which he called attention to some of the points in the conic construction which were of an architectural nature, which he said gave him and those associated with him considerable thought.

The paper was illustrated by copious drawings by M. Hasenauer, from which, Mr. Russell remarked in conclusion, it would be seen that the great dome was not, as many supposed, a mere separate isolated structure, but that it was incorporated with the vast area of smaller buildings all round it, so as to be an integral portion of a whole group.

THE VIENNA DOME.*

We would not anticipate the discussion which is proposed to be held at the Institute of Architects upon the scientific questions raised by Mr. Scott Russell, in his lecture upon the Vienna Dome; but we cannot allow the immediate opportunity to go by for examining, in a spirit of inquiry rather than criticism, certain of the most prominent points in the lecturer's theories.

The case, as it was put by Mr. Scott Russell, may be said to stand thus:—Taking the usual hemispherical dome as representing an accepted principle of construction, irrespective of differences of material; and looking at the malleable iron of the present day as a material of peculiar characteristics,—then the conical principle is seen to be preferable to the hemispherical for the use of iron; and not only so, but the construction of a conical iron dome is found to be the scientific perfection of building contrivance.

In the case before us the diameter is shown to be 360 ft.,† which is certainly what our Transatlantic cousins would call "a big thing." But the enthusiastic "worker in iron" went on to say that he had at first proposed it to be as much as 800 ft. in diameter; and he seemed indeed to have a hidden feeling in his own mind, which modesty alone prevented him from expressing, that if the Austrian Government had been sufficiently adventurous, it might have been 8,000 ft., and he at any rate would have never demurred. And, to tell the truth, we do not at first sight perceive any reason why he should object to even still more magnanimous dimensions, except the totally unscientific consideration that, although in one sense it is the mind that is the stature of the man, yet in another it is on an average about five feet six.

The mode of construction, if we rightly understand it, is as strikingly simple as it is ingenious. The circumference is divided into segments of nearly 3½ ft. in length, making 360 of them. The cone is pitched at an angle of 30 deg., which seems to be a very fair condition for the experiment. The 360 divisions of the circumference are then made the bases of as many triangles of extremely elongated form, occupying the surface of the cone, and terminating together in a point at the apex. It only remains further to make these 360 triangles 360 sheets of iron, riveted edge to edge, and presto! the dome is done. If you desire to leave an eye in the crown, so be it; the dome is still complete. If you desire to give to the structure the character of a skeleton frame of open work rather than that of an imperforate vault, so be it again.

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* Review of the foregoing lecture by "The Architect."

† By the way the lecturer began his scientific exposition by the remark that his dome was 360 ft. in diameter, and 1,080 ft. round. Such a slip as this was at least discouraging to his audience. We cannot suppose that anybody really puts the circumference of a circle at three times its diameter; but to state the case in this way is popularizing science a little too much.

You may even put a lantern on the summit, and there is no cause for anxiety. Beyond a doubt, all this is refreshing to a degree which, even in these days of brilliant engineering achievements, is most unusual; it gives one's ideas of science a thorough shake-up.

So much for the cone. The lecturer then described the enclosure to which it had to be applied as a roof. This may be called a skeleton "drum" of iron columns, 36 in number, with iron sill and head of circular plan. The sill rests on the ground foundation; and the head constitutes of course the base of the conical roof. The height of this drum is 80 ft. We may suppose that if it had been formed, like the cone itself, as a simple cylinder of boiler plate, the theoretical principle would have been even better preserved; but a peristyle such as has been described was of course preferable for the occasion; and here let us remark in passing that the introduction of this essentially different idea of structure for the enclosure, already suggests the possibility that the cone itself may after all turn out to be, if a structural novelty, certainly not the mathematical mystery which Mr. Scott Russell appears to think it is.

We will now imagine some bold and economical builder to resolve upon constructing a shed upon the conical roof principle. He sets out, we shall say, a circle of moderate diameter, lays in a little concrete foundation, rears thereon a cylinder of common sheet iron with riveted laps, and covers in with a cone of the same material. He cuts a door or two in the cylinder, and leaves an eye at the apex of the cone for a lantern light. He has put strengthening frames round the doors, and the like round the eye; but all else is sheet-iron with perhaps a flange at the sill and head of the cylinder. One can scarcely doubt that this edifice, barring violence, is simply the slightest and the cheapest that can be conceived. The designer has but to select the proper gauges of iron to suit the scale of the structure, and he has attained the supreme satisfaction of having economized his material to the very utmost, and disposed it to the very best advantage as regards both strength and enclosed area. Our old-fashioned idea of securing such perfect economy has been to set out an oblong enclosure and cover it with a simple span roof. But this notion is obviously based upon the use of wood framing, covered perhaps with boarding; whereas the new idea is identified with the application of sheet iron without framing—a material entirely different in every respect. For an example on a sufficiently small scale, and reserving the question of weather, wood boarding would do as well as the sheet iron, with the joints tongued in some way and a solid curb added for the sill and base of the cylinder; and for a model, cardboard would answer admirably; but, if skeleton framing of any kind whatever is introduced, let it be distinctly observed that the principle is changed; and the practical difference between wood boarding and sheet iron is that the one must be put together in widths of a few inches, while the other is supplied in widths of 2 or 3 ft. The question of wear we are excluding from our view, as well as that of resistance to violence; and structurally, therefore, we may acknowledge that Mr. Scott Russell, in affirming that the cone and drum are theoretically a novel idea of construction specially identified with the use of iron, is quite right.

But there are two or three statical arguments advanced by Mr. Scott Russell, which he must not, without at least farther explanation, ask everybody to accept as genuine. First, there is his doctrine of the antagonism of parts. Referring to girder construction, as also to trussing—let us say in the case of a timber girder, a box beam, a latticed bearer, a king post roof truss, a bow and string bridge, and an iron arch rib respectively—when we perceive, as we must admit we do, that there is everywhere an upper flange or its equivalent in compression, a lower one in tension, and an interposed web or its equivalent to preserve the element of depth (the strength being always as the square of the depth or its equivalent), he seems to tell us this:—There are here three separate forces, each of which has for its sole function the antagonistic resistance of the other two; the whole three are therefore adjusted to a perfect balance, and the failure of one of them produces the immediate destruction of all; wherefore we simply have three equal agents at work in counteraction to each other, so that two of them are manifestly waste. Surely this, if we take it aright, must be a mistake. We may grant him for the sake of argument that the web of a plate iron girder carries none of the load; but it keeps the two flanges at the required distance; and when these, so kept at that distance, act one against compression and the other against tension, the conclusion must be that both support the load, and not either; that the strength is one of addition and not of subtraction; and indeed it must be plain upon a moment's reflection that even our imaginary cone of thin sheet iron must have its compressive and tensile strains distinctly marked within its thickness. We are ashamed to introduce such an illustration here, but suppose an army to consist of three arms of perfectly equal force, infantry, cavalry, and artillery; it is obvious that this arrangement would be utterly destructive of the entire army if the three arms were set to fight amongst themselves; but if they co-operate against the enemy, that is quite another case. The two flanges and the web co-operate apainst the load, and it is vanquished; if they were no more than "antagonistic parts," the girder, to quote another idea of our lecturer's, would forthwith upon the first twist "go into gas."

Another doctrine advanced by Mr. Scott Russell is that of the co-operation of parts. In the iron cone, he says, the material is not only relieved from the condition called antagonism of parts, but it is endowed throughout with a positive quality of the opposite effect. He even went so far as to suggest, as it seemed, that every particle of the metal is placed in a state of both compression and tension, as opposed forces, a proposition which is as essentially mistaken as that of the perpetual motion. At any rate, he further affirmed, the cone and the drum, taken together, albeit the latter is a peristyle, are in such a state of perfect equilibrium, that if part of the cone were to be cut out, nothing would happen; if some of the columns were to be removed, nothing would happen; if a hurricane blew, nothing would happen, except it were the propulsion of the entire edifice along the ground; if the building were blown up with gunpowder, this would merely make a hole in it; if an earthquake occurred, no harm could be done further than some tilting of the whole structure out of level; and if the foundation gave way—well, it did not require any foundation at all, except as a kind of concession, we presume, to popular prejudice. Nay, such are the harmonious and homogeneous relations of all the parts to each other, that, if anything such as a rivet could by any impossible stretch of fancy be supposed to give way, the only result that could be conceived, said Mr. Scott Russell, would be that the entire building should "go into gas!"—a sufficiently impressive conclusion, and most forcibly asserted, but one which at least is not quite so serenely scientific as could be desired.

One other point which requires elucidation is the argument that the cone keeps the peristyle guaranteed against such an accident, for example, as the knocking down of half-a-dozen of its columns, by the existence within the substance of the iron cone of an infinite number of "parabolic and hyperbolic catenaries" which tie the head of every column to that of every other, and so render them not only immovable if untouched, but in no respect indispensable if they should be capriciously taken away. Upon this remarkable proposition we really cannot venture to make a single remark, except it be by way of inquiring whether we can possibly have heard aright. The catenary curve, argued the lecturer, is of course the curve of equable strains. But the parabola is not far off the catenary curve; the hyberbola also is a sufficiently close approximation to it. Suppose, therefore, that we accept these two conic sections to stand for the catenary, which is not a conic section. Suppose next that we draw upon the surface of the cone an infinite number of these two curves, the one corresponding with planes that are perpendicular, and the other with planes that are in every variety inclined. Then it follows, if we be right, that any threatened disturbance of any point in the circular head of the peristyle immediately sets up within the substance of the cone, the action of an infinity of parabolic chain-ties, equivalent to catenary arches, communicating with every other point in the circumference, and an infinity also of hyperbolic chain-ties, equivalent to catenary arches, similarly operating; whereby every point in the circle comes to be supported from every other point in the circle, and that in such a way as to correspond fully with the idea of infinity which is involved in this description. Can this really be the meaning of our learned doctor in iron?

Let us now turn for a moment to the common theory of the strength of domes in stone, and apply it to the case at Vienna. There are of course two modes of construction to be considered. In the one case there is a skeleton of vertical ribs carrying the covering between them; in which case the ribs must be equilibrated or otherwise secured against the cross strain of the load.

In the other case there is a series of rings; and in this instance each ring must be preserved against tension by chain bond. The latter of these two systems is identical in principle with the iron cone; the entire dome is placed in tension by its own weight; and the pressure of wind or snow increases the tension. But the equilibrium depends, if upon nothing else, upon the perfect equableness of this strain over the whole structure; and likewise upon the perfect balance of local strength in every part. To say that the whole edifice must either remain intact or bodily disappear is idle. How then is it to fail, when it does fail, as all things must? By nothing at all miraculous or even mysterious. In course of time, even with the most complete equilibration of design and the most liberal margin of stability, some part of the dome will buckle by the accident of weak workmanship; or some joint will open by the shearing strain of which the lecturer spoke so disrespectfully; or some column will settle in spite of his defiance of the foundation; or the mere irregularity of the wind or snow and the expansive and contractive influences of the temperature will bring about creaking and crankiness, which, once begun, must go on increasing in a geometrical ratio until the whole of the gigantic shell is crippled. It is not a theoretically regular pressure resting upon a theoretically immovable vault that is in question; but it is a variety of palpably irregular strains coming at will upon a mere fallible roof, exquisitely light and economical in itself, no doubt, but all the more on that very account susceptible to all such misadventures. We have only to revert, in short, to our primitive sheet iron shed, and to ask ourselves the question how this frail edifice is to break up when it does so. Let the sun's rays beat upon it for a year or two; let the winter frosts freeze it; let the north wind blow against it; let the foundation settle a little here or there. Very well, says Mr. Scott Russell, let them do their worst; there is a virtue in the circular principle of the roof-cone which nothing of that kind can conquer. Nay, we may fancy him saying, my cone is like the chain of perfect equilibrium itself; hang it up as you please, level or out of level, it is always the same; cut off a part of it, great or little, and it still retains its form; leave but a shred of it and it is a shred of the catenary; cut it in a hundred places and there are but a hundred bits of the same catenary; such a thing is perfect equilibrium! All which is in theory most admirable, at least so far as it goes. But nevertheless, our shed would go the way of all sheds, and heat and cold, wind and decrepitude, would scarcely care to snap their fingers at our theories, so sure are they of their prey. Our sheet iron bee-hive would simply "give way somewhere," and there is in this vernacular mode of expression something quite as much of the infinite as in all the fine-spun fancies of the "parabolic and hyperbolic catenaries." The thing would most indubitably give way somewhere; and the meaning of this is that so soon as the margin of stability happened to be reached in some unexpected spot, then inevitably must that spot become the "weak point" upon which all the natural agencies of wreck shall concentrate their forces until a breach be made.

A last question shall be this:—Why prefer the form of the cone to that of the curved dome? Although there is no special virtue in the mere circularity of an arch, except as the representative form of a corresponding equilibration; and although indeed the earliest of all arches is the simplest, namely, that of the narrow passage in the Egyptian pyramid where two stones lean together in the form of the inverted V (Λ), yet an arch is an arch in whatever material, whether as a stone bridge or a cambered beam, and then why should the Vienna cone be pitched in a straight line and not in a curve? Is there, as matter of fact, any camber in the 360 triangular sheets that radiate round the lofty eye of the structure? If not, why not? If so, then where is the cone as distinguished from the dome?

It is not perhaps perfectly easy to say what are the æsthetics of the question, but certainly we may venture to imagine that most architectural critics, if not all, would pronounce the straight slope of the Vienna roof to be clearly inferior in graceful form, and still more so in the particular effect of impressive grandeur, to a curved slope of whatever pitch, that is to say, a common dome of whatever elevation from the most oblate to the most pointed. If so, we can see no reason why Mr. Scott Russell's mode of construction should not be applied to the curve as easily as to the straight. It is but to set out his elongated triangles as spherical instead of plane; this is easy enough, and the riveting of the flanges is the same; and if one had any momentary misgiving about the manipulation of bent iron, they instantly disappear in view of the magnitude of the dimensions, by which the necessity for bending, even vertically, becomes virtually nil.

One thing which we must remark is that Mr. Scott Russell's description does not appear to include anything like vertical ribs in the construction of the cone, although the photographs indicate something very like them. If there are ribs of any kind at all, the question is whether this does not overthrow the entire argument about the peculiar virtues of the conical form.

On the whole we take leave to submit that the case for the peristylar enclosure or wall work is not made out at all; and that the theory of the cone, although its practical excellence and intrinsic novelty are unquestionable, requires further elucidation or none at all. But we congratulate Mr. Scott Russell very heartily upon the enterprise of thought which characterizes the whole of his discourse upon the subject.

COMPASS ADJUSTMENT IN IRON SHIPS.*

From "Nautical Magazine."

There is no instrument in an iron ship on which life and property so much depend as the compass. There is no instrument that equals it in being answerable for so much loss; and there is no instrument, I fear, that gets less practical consideration. To a certain extent, the laws which govern other instruments come within easy range of our comprehension, and we can compensate for changes, or ascertain errors and rates, and the mischievous influences they are subject to; but the magnetic disturbance of an iron ship is so subtle in its action, and assumes such various phases, and is so continually changing with change of locality and other causes, that it becomes exceedingly difficult to govern by any permanent method. Indeed, so far, it cannot be done.

It is not necessary that the navigator should be able to make a chronometer, or that he should understand all its complex mechanism. All this, and its rating, he may safely leave to its maker, and every additional chronometer he carries answers the purpose of being a check, and making his position more certain. But it is otherwise with the compass. If he leaves this exclusively to its maker, without testing either its action or adjustment, he imperils life and property by his short-sighted trust; and, so far as a change of magnetic disturbance is concerned, any number of compasses he may carry are no more use to him than one, as every change affects the whole.

The navigator will, therefore, do well not to place any dependence on his compass, until he has himself tested its quality, its suitableness to his ship, and the value of the adjustment. To do this as early as opportunity offers, on a voyage, ought to be regarded as an imperative duty. On his own knowledge only of the compass should he risk life and property in shaping a course, and not on an irresponsible adjuster, whose adjustment after all, even if properly made, is of limited value, except for the locality of the adjustment.

Although life and property are so dependent on a compass adjuster, any one that chooses can set up as one. Without he is a well-known man, there is no guarantee that he knows anything about the duty he undertakes to perform. He is not called upon to pass any examination, or hold any certificate, and as he may be dependent on patronage in his business, he can consequently give no guarantee to life and property, that he can take an independent stand, and stave off the pressure that may be brought to bear upon him to do his work in one-twentieth of the time necessary. In shaping a course, therefore, on a thick night, in a narrow channel, with much life at stake, what confidence is he calculated to inspire, or is he worthy of? The over-confiding navigator, unfortunately, gives him too much, and, consequently, too often comes to grief.

But, supposing the compass adjuster not only to be thoroughly acquainted with his duty, but getting his own time to do justice

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* A paper read by Captain John Miller, at the Liverpool Mercantile Marine Service Association.

to his adjustment. When shaping a course down-channel on a thick night, to what extent can his adjustments be relied on? His method of adjusting and obtaining his tables is very fallacious and very incomplete. In a still-water dock, with an upright ship only, surrounded with a crowd of iron vessels, he places down a number of permanent magnets, swings the ship, and takes a table of deviations. How long do these tables hold true? In some cases just as long only as the ship is in the dock. But, doubtless, after a voyage of constant changing, when under the same condition of things he again swings the ship, he will obtain the same results. This return of the compass to the original deviations, has often led to the erroneous conclusion that there has been no change since the original adjustment, when the truth is, the compass has never been the same from the time the ship left the dock until she again returned to it.

The table of deviations, handed to the navigator, often shows a balance of the ship's disturbance, amounting to a whole point or more of the compass, remaining uncompensated. When it is remembered that a disturbance that produces on any one point such a deviation, destroys on another point one quarter of the whole directive force of the needle, it will be seen how unreliable such a compass would be, going at any great speed, on a dark night in channel, when a good lookout would be little or no preventive against loss. In such cases it is highly important to the navigator that the strange vagaries that such a compass, on some points, is liable to should be well understood, for he may be unconsciously steering on the very point on which the directive force of the needle is most destroyed, and then he is very liable to go wide of his intended course: the weather, if rough, and the heeling having a great deal to do in influencing the course the ship will make.

These tables, again, are calculated to mislead those who do not study the compass for themselves; for the tables are not limited in their application to any locality, but handed to the navigator in a form as though they applied to the whole surface of the globe. Doubtless, many have regarded them in this point of view, and some have come to grief in other seas through them. Now this is a very loose state of things. One would think that life and property are of sufficient importance to command something more definite for their interests. Surely, when the consequences may turn out as serious as the loss of the Atlantic, the adjuster ought to be more explicit; and, if it were only to prevent misleading, he ought to make it appear in his tables what, in his judgment, would be the range of their reliability, and for what extent of the earth's surface he intends them to assist the navigator in shaping a course.

But the greatest fallacy connected with these tables consists in its being taken for granted that the amount of deviation given on each point shows the whole influence of the ship's disturbance. This is far from being true. The ship is a huge magnet; or, more correctly speaking, one large magnet, and a number of smaller ones indiscriminately placed, and revolving, as the ship steers on different courses, under the compass. When the influence of the disturbance is acting at right angles with the needle, it then produces on the compass the greatest amount of deviation, and it is only when there that the amount of deviation may be said to show the full value of the force of the disturbance. On many points it shows a reduced value, and on some points it shows none, though the disturbing medium is in no way removed from the compass, but is operating for mischief equally on the point which shows no deviation, as it is on the one showing the greatest.

To make this plain, let us suppose our performing the following experiment:—Having a single needle compass, let us obtain another needle or magnet of the same magnetic force. Let us place this magnet on the card of the compass. It will be evident what will be the effect, if we place the North Pole of the disturbing magnet on the north of the compass, with the South Pole on the south. The needle and the disturbing magnet will, of course, in this case be acting together, and there will be no other effect than that of increasing the directive force of the compass. But let us next place the disturbing magnet on the N. E. and S. W. points. The result will be to produce a deviation of two points. The N. N. E. point will then take the place of the north and point to the magnetic pole. Next let us place the magnet on the east and west points, at right angles with the compass needle. In this position, the disturbing magnet produces the greatest deviation, which in this case will be four points, the N. E. point now taking the place of north.

Now, it must be evident that while the North Pole of the disturbing magnet is on any of the north points, the directive force of the compass must be more or less increased. These points, therefore, become steady ones; and, after applying accurately to them the deviation, they will make satisfactory courses.

But when we place the North Pole of the disturbing magnet on the south points, the action of the compass is very different. It loses its steady nature, becomes fickle and oscillating, and unreliable for making a course; because, in this case, the directive force of the needle is more or less destroyed, according to the position of the pole of the disturbance. Let us place the North Pole of the magnet on the S. E. If the result be of the same uniform character as with the experiments on the north points, the deviation ought to be again reduced to two points. But there is nothing uniform in the action of the compass, when the disturbance is thus neutralizing the directive force of the needle. It will make a course according as it is influenced by the ship's heeling, or rough weather. At one time it will show one deviation, and at another time another; and it has, consequently, often led to the conclusion that the ship's disturbance was subject to sudden and great magnetic changes. In 1854, the late Dr. Scoresby contended with the Astronomer-Royal that it was so subject; and, in the loss of the Tayleur, he tried to prove that it had taken place, and was caused by the heavy blows of the sea. But time has shown that this was not the case. There was no change of magnetic disturbance. The directive force of the disturbance was simply acting against the directive force of the compass, consequently neutralizing it; and the ship and nearly 300 lives were lost.

With the disturbing magnet on the S. E. point, the deviation is but little less, and the compass has but one-half of its directive power neutralized. Let us next place the North Pole of the disturbance on the S. S. E. Here the deviation shown will be considerably reduced, but the compass has three-fourths of its directive force destroyed, and is almost useless, though the deviation given is but small.

This shows how important it is to the navigator to know how the disturbing force is operating on the course, whether it is increasing or decreasing the directive force of his compass, and this he must work out for himself, for from an adjuster's tables he can learn nothing about it. This shows also how these tables may mislead the navigator, by ministering to a false security, for as they do not show anything of the increased or decreased magnetic force of the compass, the small deviation given on some points conveys the erroneous idea of a small disturbing influence acting on the course, while every compass has, acting on each one of its points alike, a disturbing influence equal to its maximum deviation, the whole, in one case, going to increase the directive force of the needle, and in another to neutralize it; and in two others, when operating at right angles with the needle, to produce circular deviation exclusively.

If we now place the North Pole of the magnet on the south of the compass, with the magnet we have supposed, the whole directive force of the compass will be destroyed. But let us suppose, for this point, the power of our distributing magnet reduced to two-thirds the directive force of the needle. The compass will then act, but there will be no deviation produced. The needle will point to the magnetic pole as though no disturbing magnet were there; there is no effect to produce deviation, the whole force of the disturbance having gone to neutralize two-thirds the directive force of the needle.

In these experiments, I have supposed our using a disturbing power equal to the directive force of the needle, which will always produce four points deviation. But it is not to be supposed that, in these days, any ship goes to sea without having such a disturbance reduced by compensation. My object in using a magnet of equal force, is to show a rule of measurement of the disturbance, which will always be more or less useful. Thus we know, for example, when the maximum deviation amounts to four points, the disturbing force is just equal to the directive force of the compass; and, consequently, when the forces are acting reversely, the compass is dumb on one point, and nearly so on others. When, again, the maximum deviation is two points, the disturbing force is just one half; and when there is but one point, the disturbing force is one quarter, and there will, of course, be half and quarter results.

It will, I think, now be seen that every iron ship's compass, having an amount of uncompensated disturbance remaining, must have all its points affected for steadiness or fickleness. Steadiness, when the proper pole of the disturbance (which will be the south when it is free from the compass) is acting on the north, and fickleness when the reverse. I use this latter term to distinguish it from sluggishness. A compass becomes sluggish only from its own defects, such as defective pivots and agates. These, when defective, give rise to an action —or, rather, want of action—which is very appropriately called lazy, or sluggish. But fickleness, arising as it does from other causes, and which affect alike with the sluggish the most perfect compass, shows itself, not in a want of action, but in an action peculiar to itself, and which heavy-weather motion will develop into oscillation.

These fickle points sometimes show themselves as soon as a ship is at sea, if the ship's course happens to be on one of them, and there is sufficient lift of a sea to make them active. They become apparent when the helmsman, without noticing the ship's head, attempts to steer by the compass exclusively. In this case he labors hard to steer. The wheel is not one moment at rest in his hands, and it is one constant grind with him, in his abortive attempts to keep the course and lubber point in one.

Heavy weather develops these fickle points into points of oscillation in high latitudes, and the compass, while the ship's head is on one of them, becomes of no use for steering purposes; and while swinging a ship at sea, by a process which I shall now explain, they often give different results.

By this process of swinging, the navigator can test for himself the quality or action of his compass, the value of the adjustment, and the deviation table taken in the still water of a dock. He can also ascertain the steady and the fickle points, and measure the amount of fickleness left by imperfect compensation, or produced by permanent compensating magnets, after sailing into localities for which the adjustment does not answer.

With the aid of the stile on the compass, which I invented many years ago, and published in 1854 in the July number of the "Nautical," and which is now very generally attached to a steamer's compass, it is a simple and speedy process to swing the ship at sea, and obtain, by the shadow of the stile on the card, the bearing of the sun, or magnetic azimuth on every point of the compass, as the ship goes round. As many compasses can be taken at one time, as there are reliable observers to read the position of the shadow as the ship revolves. Suppose there are four good observers and four compasses, four ordinary men will do to assist them, by intimating the moment the ship's head is on each point, so that the observer's attention is not taken from the shadow, except to mark down its bearings in prepared tables. One compass, the standard, can be taken for navigating purposes exclusively. Three compasses will then be left to perform any experiment that suggests itself to the navigator. He can leave the second one with the adjuster's magnets surrounding it, if he wishes to test the value of dock adjustments. From the third, he can take away all the magnets, to obtain what I call the natural deviation—that is, without magnets; and, if he already knows the natural deviation of the fourth, he can apply one compensating magnet to learn the value of its effects; and, in after swingings, this magnet can be tested for every variety of position and place. With all the results noted, the whole can be repeated with two magnets, and afterwards with three, and so on to any number, until he understands the value of every variety of compass adjustment, or until he has discovered perfect compensation, or is satisfied it cannot be obtained.

The first thing to be considered before swinging is, whether the sun will remain unclouded for half an hour. If satisfied that he will be able to cast a continuous shadow for that time, the observers may take their stations, each one being supplied with a blank table, having in its first column the points of the compass. Any point will do to commence on; but let us suppose we are steering S. W. by W. We then give the order to the observers to commence their notings on west. The speed of the ship is then slackened to nine knots, the altitude of the sun is taken, and the helm is hove over to hard-a-port. The ship gets up her full revolving speed by the time she reaches west, and the notings of the shadow on each point of the ship's head then takes place as the ship flies round, which she is allowed to do, until she reaches W. N. W., when the helm is immediately hove over, hard to starboard, and the readings again commence when the ship reaches west. The ship flies once more round, until the last point to be noted is reached, when the sun's altitude is again taken, the ship set on full speed, and put on to her course.

The time taken with the two revolutions is about 25 min.—an insignificant loss in a ship's passage, compared with the value of the results to life and property. By this simple process we obtain the means of knowing whether there is any defect in the compass itself; whether the adjustment is of a respectable character, and how far for making a course the compass may be relied on. It will, of course, take some time to work four compasses, and all the problems necessary to complete the tables; but the navigator can work them as he obtains leisure, and they are not, in spite of their numbers, half as difficult as they may appear. By applying a little method, and with a little practice, the difficulties presented by the imagination soon vanish.

Before working them, however, a mere glance down the columns of bearings will reveal much of the state of the compass; for, if it was without disturbance, there would be no variation in the whole revolution of the position of the shadow on the card, except the little due for change of sun's position. Revolving the ship different ways will, of course, give different results, owing to the ship, while going round, dragging the card after her. This dragging, however, can be turned to account. We can make it reveal to us the state of the pivot and agate.

Looking down these columns of bearings, you can see whether it is worth the trouble of working them, or whether it will be necessary to have the compass re-adjusted. If the changes in the readings are not uniform, but very irregular, and the shadow has taken one or two great jumps, while the ship's head has passed from some one point to the next, you at once see whether they are worth the trouble of working.

If deciding in favor of working them, the next thing to do is to obtain the sun's true azimuth by the two altitudes taken. The difference between these, divided by 64, for the number of points, will give the amount of change of the sun's true azimuth for each, amounting somewhere to about five seconds. It is easy to write down continuously for the heads of problems the whole 64 points of the sun's true azimuth from mental calculation. Next place underneath each the magnetic azimuth for every point. Next take the difference for the whole 64; next write down the variation under the whole of the problems, which must be accurately obtained for the ship's position from a chart of magnetic curves, and next apply it by adding or deducting from the whole error, according as they turn out of the same or contrary names. With this method and a little practice, the working out of the whole 64 problems for each compass will soon become a mere mechanical performance, worked out as fast as black lead can be made to travel.

With, then, the port and starboard helm deviations worked out, enter them in the fourth and fifth columns. Next work out the mean deviations, and place in the sixth column. Next take the difference between the two deviations, and place in the seventh. Add up this column and divide the sum by 32, the number of points. The remainder will be the mean drag of the card, and the amount that would be shown on every point, if the compass was free from magnetic disturbance. The eighth column-head as, Steady Points and Value, and the ninth column-head as, Fickle Points and Value, and proceed to work out and fill up each column, thus:—Take the difference between the mean drag of the card and the difference between the port and starboard deviations. When the latter is less than the drag of the card, the difference is the value of the increased directive force, which enter into the column of Steady Points; but when the difference between the two deviations is greater than the drag of the card, the difference between the two is the value of the decreased directive force, which place in the column of Fickle Points, and the table is then complete.

I have before me now such a table for a steamer's standard compass, elevated 18 ft. above the deck. This table has been selected out of many; because, the compass being defective, and a standard compass of such elevation, any defects in its action will better illustrate this paper, for from such a compass we naturally expect the best performance. I have chosen it, also, because it shows as great a deviation as is safe to leave uncompensated on any compass on which we have to depend for making a course in such a high magnetic latitude as the Channel.

CALIFORNIAN, *s.s., Standard Compass Deviations, Revolved April* 22*d*, 1873, *Lat.* 50 *deg. N., Long.* 13 *deg. W.*

1. Compass Points.	2. Port Magnetic Azimuth.	3. Starboard Magnetic Azimuth.	4. Port Helm Deviation.	5. Starboard Helm Deviation.	6. Mean Deviation.	7. Diff. of Port and Starboard Deviations.	8. Steady Points and Value.	9. Fickle Points and Value.
North	S. 45° E.	S. 28° E.	16° 57″ E.	3° 1″ E.	9° 59″ E.	13° 56″	....	0° 16″
N. by E.....	45	27	17 5	1 53	9 29	15 12	....	1 31
N.N E......	42	25	14 13	0 15 W.	6 59	14 28	....	0 47
N.E. by N..	41	20	13 21	5 23	3 59	18 44	....	5 3
N.E........	38	17	10 29	8 31	0 59	18 59	....	5 19
N.E. by E..	31	15	3 37	10 39	3 30 W.	14 16	....	0 35
E.N.E......	28	15	0 45	10 47	5 1	11 32	2° 9″	
E. by N.....	25	15	2 7 W.	10 53	6 31	8 48	4 53	
East........	22	10	4 59	16 3	10 31	11 4	2 37	
E. by S.....	18	10	8 51	16 11	12 31	7 20	6 21	
E.S.E.......	15	8	11 43	18 19	15 1	6 36	7 5	
S.E. by E...	13	6	13 35	16 27	15 1	2 52	10 49	
S.E........	17	0	13 45	22 19	18 1	8 36	5 5	
S.E. by S...	18	0	12 35	22 27	17 31	9 52	3 49	
S.S.E.......	20	3	10 27	19 35	15 1	9 15	4 26	
S. by E.....	22	10	8 19	12 43	10 31	4 24	9 17	
South.......	24	13	6 11	9 52	8 1	3 41	10 0	
S. by W....	30	14	0 13	8 59	4 36	8 46	4 55	
S.S.W	35	17	5 5 E.	6 7	0 31	11 12	2 29	
S.W. by S..	38	20	8 13	3 15	2 29 E.	11 28	2 13	
S W........	42	20	12 21	3 23	4 29	15 44	....	2 3
S.W. by W.	45	24	15 29	0 29 E.	7 59	15 0	....	1 19
W.S.W.....	45	24	15 37	0 21	7 59	15 16	....	1 35
W. by S....	53	24	17 45	0 13	11 59	17 32	....	3 51
West.......	50	27	20 55	3 5	11 59	17 48	....	4 7
W. by N....	50	27	21 1	2 57	11 59	19 4	....	5 23
W.N.W.....	55	25	26 9	0 11 W.	12 59	26 20	....	12 39
N.W. by W	55	25	26 17	0 41 E.	13 19	25 36	....	11 55
N.W.......	53	27	24 25	2 33	13 29	21 52	....	8 11
N.W. by N..	49	30	20 33	5 25	12 59	15 8	....	1 27
N.N.W.....	49	28	20 41	3 17	10 20	17 24	....	3 43
N. by W....	47	28	18 49	3 9	10 59	15 40	....	1 59
	42 30	30			32)	438 36		
					Drag of Card	13 41		
2)	72							
2)	36							
Inner Deviation	{ 18							

I have before intimated that when revolving the ship, if there were no magnetic disturbance, the shadow of the stile would be stationary on the card, excepting the little alteration due for change of sun's position. In the second column of this table, the difference between the highest magnetic and the lowest is 42 deg., so that while the ship was revolving with her port helm, the north point of the compass was moving forward and backward through an arc of 42 deg., although elevated 18 ft. above the deck. This column shows also a jump of the shadow as the ship revolved from N. E. to N. E. by E., amounting to 7 deg., and another jump as she passed from W. S. W. to W. by S., of 8 deg. The sixth column, giving the mean deviation, shows the maximum to be 18 deg. 1 min., and occurs on the S. E. point. The drag of the card, deducted from the 8th column, is 13 deg. 41 min., which is a very high drag, and proving the compass to be very sluggish and defective, though it had answered very well on the voyage while crossing the rough Atlantic homewards. It was, however, unfit for a smooth-water channel. The card which had only a single needle, was therefore condemned, and with a new double-needle card and pivot, after revolving the ship again on the following voyage, in about the same locality, viz., in the Channel, the drag was 4 deg. 20 min. The drag of the card increases with the increase of latitude, consequent on the increased dip of the needle, and is very small in low latitudes. In columns eight and nine the highest value of the increased directive force shown on the S. E. by E. point is 10 deg. 49 min., and the highest for the decreased directive force is 12 deg. 39 min., and on the W. N. W. point.

It would extend this paper to too great a length to go any further into the subject. The amount of change of the compass between this and the magnetic equator, and the effects of applying one or many permanent or movable magnets, could only be illustrated by numerous tables; and I think this paper has already gone the usual length of such productions. I shall therefore leave the further consideration of the subject until some future opportunity, as I wish, before concluding, to apply what has been said to the late appalling disaster, the loss of the Atlantic, and inquire how far the compass had to do with it.

The inquiry held on her loss accounts for it by the absence on the part of the commander of the use of any of the ordinary precautions in approaching land. All this is very well so far as it goes. But for those who have to navigate life and property safely in similar circumstances, something more is wanted; something that is more defined to the perceptions, something that the understanding can erect as a beacon to warn of the precise nature of the danger, and the something that was the cause of this absence of all the ordinary precautions in approaching land.

Like the compass, man also is subject to disturbing influences; and these often produce on him extraordinary deviations from his general course of life, even sometimes to the extent of neutralizing all his directive force for discharging the claims of duty. This is as true in business as it is in anything else. The successful man of one time becomes the unsuccessful man of another, and the man of well-known ability sometimes commits greater mistakes than one with an ordinary amount. No one's life is free from disturbing influences. The navigator is not exempt any more than others from this general failing, and when it occurs with such dreadful consequences, as in the case before us, it is very desirable to know what was the nature of the disturbing influence, and in what form did it operate on the commander's mind to produce, with such a host of life and so much property at stake, such a great effect as the neglect of all the usual precautions in approaching land.

The natural influence operating on every man with so much life and property in charge, and driving a ship on a dark night at such a speed towards land, is to make him feel exceedingly uncomfortable and restless until he has adopted some precaution to satisfy this great call to vigilance and action in his nature. No one is exempt under such circumstances from this call. It is the voice of intelligence stimulating to caution, and will produce it, unless there is some disturbing influence in the way. It will not be silenced, but will banish from the subject all rest and sleep until he meets its promptings and satisfies its claims, either really or supposed.

In the case of the Atlantic, the judgment of the Court intimated that no precaution had been used. The question thefore is,—How were the calls of this voice in her commander silenced? For though he seemed to have responded to it when he kept watch on the bridge from eight to twelve, he nevertheless afterwards lay down and slept, and slept soundly too, a sleep that proved the sleep of death for many hundreds of human beings. This sleeping was an impossibility, without he had previously worked out in his mind something on which he could rely; and as he did not resort to any of the usual precautions, it is evident that, on whatever he was relying, he was doing so with unlimited confidence, and one that with him seems to have precluded the necessity of having to resort to anything beyond.

On what, therefore, could he have been relying? It was not the lead, for he did not use it. It was not his distance run each hour, for he took no steps to obtain accuracy; and it was not any special lookout, for there were no extra orders given. The question is inexplicable, unless we conclude that it was his compass and his course.

It can be easily understood how the usual precautions may be neglected, and the navigator even obtain sleep under such circumstances, when he has fixed in his mind that the course he is steering will give proper results. No doubt, when shaping his course, he did so with the intention of making Sambro Light, either right a-head or a little on the port bow, and this confidence he seems to have had in so making it, explains why there was the absence of the use of every other precaution. All these extra precautions would appear very superfluous to a mind already satisfied of being certain to make the Light, and he evidently was carried away by the feeling that he would not only make the Light in time to avoid danger, but also in time to make it worth while to slacken speed for daylight.

This confidence in the compass may have been acquired through previous voyages, making lights as expected, when steering on her regular voyage courses; and this was doubtless added to by the one precaution which was certainly made, viz., that of obtaining an azimuth after bearing up for Halifax. But it is a mistake to suppose that because the compass will give good results steering on some points, that it will therefore do so on all, or that one azimuth will show the compass to be reliable. It may do so when steering on any point where the directive force of the needle is increased by the disturbance, but it is otherwise if steering on any of the points where this directive force is more or less neutralized, and any change in the ship's heeling would make its action more uncertain.

If there is any truth in this reasoning, it follows that it was the unlimited confidence exercised in the compass that was the disturbing force which produced the neglect of all the usual precautions in approaching land, and led to this terrible disaster.

In conclusion, I have to say that it was the loss of the Atlantic that suggested this paper, and I therefore feel that it would have been incomplete without some reference to it. Not that I have any wish to cast reflection or sit in judgment on the unfortunate, but because I have a wish to contribute my mite towards the prevention of the recurrence of such dreadful catastrophes.

THE HYDRAULICS OF GREAT RIVERS.

From "The Building News."

The largest rivers on the earth are those of South America, and M. Revy undertook, a few years ago, to survey the Paraná, the Uruguay, and La Plata; the last, however, being an estuary of the South Atlantic. The main purpose of the examination was to settle some difficult and obscure questions of hydraulics, which, in Europe, could not be determined, since neither the Rhine nor the Danube are of sufficient vastness and power to be taken as criteria. And, as it happens, the three mighty watercourses of the world were within the limits of the Argentine Confederation; great in their depth and width, and, even to this day, in their upper channels, unexplored. But, assuming that where their course is known, it is an excessively onerous task to trace their lines of practicable navigation; their banks, currents, tides, and winds; the nature of their beds; the geological formation of the surrounding country—and particularly so when a flood, pouring down, hundreds of miles, from undiscovered sources, is, at its narrowest, equal to the breadth of the British Channel. The engineers engaged, indeed, confessed that all their levellings failed to disclose the actual fall of the Paraná; that numbers of their experiments were of scarcely any practical value; and that, with a river to deal with many times larger than any in Europe, they were continually baffled. Their measuring rods, floats, and plummets were perpetually deceiving them; their planks, poles, and chains often failed at the critical moment; and the work was carried on under every possible circumstance of discouragement. Their first efforts were directed towards the Palmas branch of the Paraná. Up this they sailed a hundred miles without hitting upon a suitable spot for the commencement of their investigations, as if the point where a river pours itself into the sea were not the most important of all. They then made important observations. The water beneath them varied from a depth of 70 ft. to one of 170, a fact of no good omen to the future commerce of those regions. It was found, too, that the Paraná, like the Nile, is subject to periodical rises and falls, far beyond the tidal reach, and due to the variation of the rains—that is, so far as the truth was ascertained by the American expedition. A ship's log, although a valuable apparatus at sea, was found to be of little use. Current meters exhibited more distinct results; but even these represented the superficial rather than the principal current of water; and even then the drifts of sand and soil were apt to interfere with the action of the machinery. Boats had to be stationed on the watch; remarks had to be recorded every 5 min.; electric wires were touched; bells were sounded; and at intervals temporary observatories established. In the result, the "River Plate," popularly so-called, is discrowned from its position next after the Amazon, as "The Queen of Rivers." It is (so the explorers declare) no river at all; but an immense estuary, in which the sea is being perpetually displaced by the sweet waters of the Paraná and the Uruguay, having no drainage area, and no original flood of its own. According to this authority, therefore, we must so far change the configuration of the South American Map as to promote La Plata from the rank of a river to the dignity of a sea, though it is rapidly becoming a marine ruin, crowded with banks, islands, deeps, shallows, lagoons, and a confusion of waves, due, in great measure, to the influence of the sun. There is nothing more interesting in the American report than the memoir on "the interference of the sun." With the appearance of new moons, moreover, violent tidal disturbances are registered, with midnight and morning gales, travelling at the rate of 500 miles an hour. Indeed, such events have been known in connection with those rivers as tidal waves driving the currents back towards their sources, and heaping above them nearly two yards depth of salt water from the South Atlantic. But these waves are too vast to be visible. Their approach is never announced by any peculiar phenomena. Indeed, no universal law respecting them has hitherto been recognized, their fluctuations being so frequent and uncertain, and differing so greatly between the bottom and the surface. The latter is of interest, but not of any considerable importance; the former, by which it is generally possible to determine the mean current, is of the highest value to the hydraulic engineer, with reference to the clearing of channels, the execution of works, and the maintenance of inland anchorages. Nearly all depends upon the inclination of the bed, with the depth and width of scour. But, as an adjunct of the sea, La Plata ought, properly, to have no fall. In association with it, we have the monotonous Palmas river, running only 2 ft. below the common level, irrigating a wearisome grass-land, moistening the roots of interminable willows and poplars, deep throughout, easy of navigation, and with a rise and fall to be counted by inches. This body of water passes by many of those ruins which attest the existence of an ancient civilization in the land, though they are, as yet, unacknowledged and unfixed upon the maps of archæology. But it is, in its characteristics, entirely different from La Plata, though their currents are so intimately associated; the Palmas, in fact, does that which the late Sir James Graham, in a famous speech, ridiculed as an impossibility — it runs for several miles uphill, thus proving the power of a tidal wave, rushing inwards from the sea. Then, with respect to the Paraná, a stream practically unknown in Europe, and with which engineering has had, as yet, little to do, we have ample information stored up in the Hydrographic Department of the Admiralty, but it is not yet offered in an accessible form. The pilots of the Paraná never look at a chart; they grow up in their special profession; they become familiar in their boyhood with the many-channelled stream; they know its every winding, and every tree or timber clump upon its banks, and they are invaluable as pilots; but, as for the country they inhabit, they know nothing about it whatever, nor, with reference to the river itself, have our geographical analysts been much more successful. They say, confessing the ignorance of what is called science upon this point, "it is important this should be clearly understood; it is rarely that we have an opportunity to fathom the laws of nature; the effective inclination, at any point, along the course of a river is a most troublesome quantity: it entirely escapes observation. It is always changing, and we never know what it really is." And now to apply practically the studies of the American engineers. They say, to commence with, that they "never will improve an observation to make it agree with accepted views and ideas." This, of course, is the only principle upon which such surveys can be scientifically conducted; any other would be no more than the bolstering up of a theory. They, in South America, have demonstrated two facts:—they place the question beyond doubt, that the principles hitherto accepted when the movements of water in open or confined channels were at variance with those of ordinary nature, and that the river navigation of the world is still a supreme difficulty and mystery. Nevertheless, a close relationship has been established between depths and currents, a fact the value and meaning of which it might be impossible to exaggerate. The greatest current, it has been proved, is at the bottom; the lightest, though apparently the most active, on the surface; but by engineering improvements they could be equalized, to the infinite advantage of passenger traffic, trade, and irrigation. No doubt all these South American streams are apt to flood their banks in the rainy periods of the year, while in others, they shrink in their bottoms, and are hardly available for even timber-rafts; yet there are other circumstances which interfere with the proper importance of great rivers. A section may be made anywhere across; but the selection of a fitting place, and opportunity for it, is often a cause of no inconsiderable embarrassment. Every hydraulic engineer can perceive, too, at a glance, that a sudden bend may seriously interfere with the formation and action of currents. "It may create," says a distinguished German writer, "a kind of revolution against established principles and laws. Order and law appear subverted, and confusion to reign supreme." When we reflect upon the immense importance, to all countries, of their navigable rivers, the value of this observation will be manifest. Railways may be of priceless consequence to the community; still no ironway, however magnificent, could compensate the capital of Great Britain for the loss of the port of London. What would France be without the Rhone, the Saone, the Seine, or the Loire? Or Germany, deprived of her Rhine and, all geographical disputations set aside, her Danube, with the dim and narrow ferry at Donauwerth? The Neva is the European gateway of Russia, as the Volga is to her Eastern territories; and most nations have understood and represented, through conservancy and other administrations, the national validity of these interests. But in the Eastern world we can have no practical idea of the problems which have had to be solved by the South American Commissions.

To comprehend their magnitude is possible only by comparison. The Danube and the Thames are no better than streamlets in contrast with those mighty waters. The Mississipi, boastfully called "the father of rivers," though long, deep, swift of flow, and steep of fall, is a rivulet by the side of the Paraná. Of whatever size, however, these volumes of water, whencesoever coming, may be, their distinct demarcation on the map, and a full knowledge of their applicability to the purposes of civilization and commerce, cannot fail to be useful in a high degree. The proper application of the principles to be derived from the survey of great rivers must be productive of improvements, although circumstances may vary their influence. Within a river, for example, in an estuary, it is practically illimitable; while we have it upon the highest authority, albeit somewhat to our surprise, that "by deepening the channel of a river, various effects may be produced which will be beneficial in some respects, and injurious in others." They are difficult powers to deal with—these contributions from the mountains to the oceans. They inundate the land; they fling dangerous bars across indispensable outlets; they silt up to the spoiling of harbors; and, in the case of estuaries, their caprices have frequently been nothing less than ruinous.

In order to the completion of our defective knowledge on these points, and our scientific preparation for the future, the most elaborate apparatus possible has been contrived, with meters to measure currents, vanes to indicate the direction and force of the winds, wheels to throw up any turbid or gritty water which may interfere with the clear flow of the stream, and other delicate mechanisms tending to the development of a science comparatively new. The attention bestowed by the learned classes in the Old and New World upon these inquiries may be readily accounted for. A very large proportion of the information obtained was novel.

Even now the Parana has not been traced to its original fountains, although boats have pushed up against its stream for a distance of several hundreds of miles; while, for the upper regions irrigated by the Paraguay, we have still to depend upon the old Spanish travellers. The crews of surveying craft have, moreover, to be especially trained to their duties, as are the subordinate explorers of such interiors as those of Africa and Asia. But although the issue of the great American enterprise has not been commensurate with the hopes or the ambition of its promoters, a great mass of information has been added to the knowledge of the world, and a way laid open for future enterprise upon those paths which, according to Humboldt, would reveal more secrets than the monuments even of Assyria and Egypt.

PEAUCELLIER'S PERFECT PARALLEL MOTION.

From "Iron."

Outside the calm concentred world in which mathematicians live and think, there are few, perhaps, who would attach anything like adequate importance to the lecture recently delivered before the members of the Royal Institution by Professor Sylvester, or dream that within the modest title of "Parallel Motion" is comprehended a problem, the solution of which has occupied the anxious attention of many most eminent geometers in this and other countries for some scores of years. Had the question no other interest than this, we might possibly have shared the too-general apathy, and not have felt ourselves called upon to deal with it in these columns; but there cannot be a doubt that the discovery which Professor Sylvester has been the first to make publicly known in England is one destined to work a great revolution in mechanical science, and therefore one in which the majority of our readers will be deeply concerned. In the opinion of the distinguished mathematician whose name is now inseparably connected with the invention, "it will give to the mechanician unlimited command over the means of transforming motion, and is an instrument that amounts to a new vital element of machinery; perhaps the most important addition to it since Archimedes' invention of the screw, about 250 (236) years B. C.; one that raises the theory of link-work to the dignity of a calculus, that enables the algebraist to fashion and write out in his study, by the rules of his science, a working plan for compelling a system to perform some of the most complicated movements that can be required for the present or any future purposes of the useful arts in their most refined and varied applications."

Mechanicians will hardly need to be told that the contrivances hitherto regarded as practical applications of the theory of Parallel Motion have been simply approximations, more or less imperfect, to the desired end.

Parenthetically, and for the sake of perfect clearness, it may be well to say that what is here alluded to under the title of Parallel Motion is in reality the conversion of circular motion into rectilinear, or the contrary, the best if not the most familiar example of which is to be found in the action of the beam and piston of an ordinary steam engine. Strictly the phrase, as applied to a contrivance for connecting the rotary motion of a beam round its centre, with the vertical or horizontal motion of a single rod is indefinite, and to some extent misleading, but by long association of ideas any combination of jointed rods employed for the purpose of causing a point to move in a straight line, or a rod in the direction of its length, has come to be so called. A well-known combination of this kind is the machine or link-work, commonly styled Watt's Parallel Motion. The essential principle of which, disguised in many modifications of form, is to be recognized in almost every mechanical combination for which the character of Parallel Motion has up to this time been claimed; but the parallelism of this invention is neither more nor less than the reduction of the perceptible circular motion to a minimum by carrying it through many changes of direction. This is accomplished by means of poles travelling in contrary curves; the action of one being supposed to neutralize that of the other, so that a point placed somewhere between the two, and equally affected by both, would follow the course of neither, but take a path of its own midway between the contrary curves, that is, a straight line. What actually occurs, however, in the case of Watt's contrivance is that this, which may be called the point of attachment, moves not in a straight line but in a curve, bearing a known relation to the varying positions of the two rods, thus describing a figure 8. This eccentric figure, however, is so small, and the consequent variation from the straight line in the working of the piston or pump-rod so slight as to be easily obviated by packing or other mechanical contrivances, and therefore the oscillation of the piston has been regarded as practically imperceptible, and its action the nearest possible approach to exact parallel motion.

That the motion, however, is not mathematically exact has long since been proved; and though from the time when Watt took out his patent, in 1784, to the date of the present invention, attempts have again and again been made to discover perfect parallel motion, they have always had the same discouraging result, until the question stood a chance of being relegated to the companionship of such mysterious and apparently insoluble problems as the qnadrature of the circle, the trisection of an angle by Euclidean geometry, or perpetual motion. One of the most distinguished mathematicians of this or any other age, Professor Tchebicheff, of the University of St. Petersburg, occupied himself for nearly twenty years, among other researches of vast importance, in efforts to solve the problem of perfect parallel motion, and though he arrived at results which gave greater accuracy than could be attained by Watt's arrangement, every step he took in the direction of a nearer approach to perfection only served to satisfy him that a complete solution of the question was impossible. So firmly convinced was he of this, that he elaborated what seemed to him almost a conclusive proof that such a machine as his exact and mathematical mind demanded was, in the nature of things, inconstructible. Conscious, however, that under some circumstances there was a bare possibility of his demonstration not holding good—that there was, in fact, an imperfect link in his chain of mathematical reasoning—he, to use Professor Sylvester's words, "with praiseworthy caution, held it back until he could succeed in patching up the flaw." Thus the matter stood until quite recently. Last autumn, however, Professor Sylvester received a visit from Tchebicheff, who, in the course of conversation, disclosed the startling fact that not only was the system of proof, which he had been so long building, still incomplete, but that it had been scattered to the winds and for ever disproved by the discovery of perfect parallel motion, first in France some nine years ago, and again more recently in Russia. The undoubted discoverer of this new power—important in its bearing alike on mathematics and mechanical science, is Peaucellier, a young French officer of Engineers, who, true to his vocation as a military topographer, and his early predilection for geometrical researches, seems habitually to have regarded the combination of link-work perfected by him as an instrument rather than an element of machinery, and as such gave to it the name of "Compound Compass." This fact may, perhaps, to some extent account for the obscurity in which the great discovery has been so long allowed to remain; but our surprise that the importance of its principles, and the universality of its application, were not earlier recognized, is in no degree lessened when we learn the circumstances attending its introduction to the world of science, for the details of which we are indebted to the kindness of Professor Sylvester.

While in Paris in 1864 on the staff of the illustrious Marshall Neil, Peaucellier spoke to Captain Manheim, of the French Artillery, Professor of Geometry at the Ecole Polytechnique, about this compass, and the latter, recognizing at once the greatness of the discovery, pressed Peaucellier to make known immediately his contrivance, and especially its principle. This he could not make up his mind to do, but was induced to send a few lines in the form of a question for solution, which appeared in "Terquem's Annals," for 1864, and fully proved that at the time of publication he was in full possession of his discovery.

The question remaining unanswered, Peaucellier was at length prevailed on to allow a communication on the subject of his compound compass to be made to the Société Philomathique of Paris, and accordingly M. Manheim brought it before that body on the 20th of June, 1867. The minutes of this sitting contain only the following notice: "M. Manheim presents considerations on the subject of the compound compass of M. Peaucellier." This was not the effect which Manheim had thought to produce, or to which he considered so important a discovery entitled, and accordingly at the next meeting of the Society he returned to the attack. In his previous communication he had made known the system of jointed rods by means of which a straight line or a circle can be traced, using the geometrical demonstration which he had discovered; and on the 27th of June he supplemented this by showing how the invention might be applied to the beam engine, fully expecting thereby to create a profound impression, but only to gain, as before, the briefest notice in the minutes of the meeting: "M. Manheim adds fresh developments to his communication made at the previous meeting." From that day forward there was no further mention of the compound compass until one of Tchebicheff's pupils in the University of St. Petersburg, named Lipkin, working in ignorance of what Peaucellier had already achieved, rediscovered his method, and made it known to the Professor, who brought it immediately under the notice of the Russian Government. An account of the results arrived at by Lipkin was shortly afterwards published at Liége, whence it found its way into M. Colignan's treatise on Kinematic, which, though published so late as 1873, refers the invention to Lipkin, and makes no mention of Peaucellier. This account, however, soon reached M. Manheim, who was not slow to claim for Peaucellier the position to which he was indisputably entitled, and which he must long since have won but that his modesty had induced him to accept the unaccountable indifference of the Société Philomathique as the measure of importance which scientific men and the public generally would attach to his discovery. To the credit of his brother officers of the corps of Engineers, it must be said that they were among the first to recognize the immense significance of Peaucellier's contrivance, and to reward him by promotion to the rank of lieutenant-colonel. The Comité de Génie have also awarded him a prize of 1,500 francs for an application of his principle to a topographical instrument.

As we have before said, English mechanicians are indebted for the introduction of the subject in this country to Professor Sylvester, who has adopted it with as much enthusiasm as if it were the child of his own fruitful genius for scientific inquiry, and who has devoted himself to perfecting many novel developments of the principle which should cause his name to be for ever identified with the discovery.

Having said so much about the origin of Peaucellier's system, we will endeavor to describe as clearly as we may without the aid of elaborate diagrams the instrument in which its principle was first exemplified.

Fig. 1.

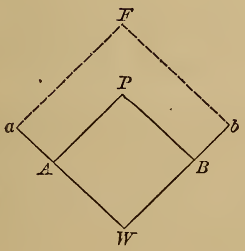


Fig. 2.

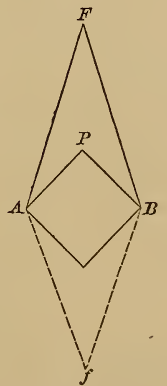
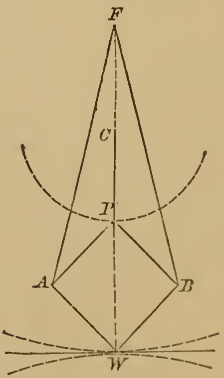


Fig. 3.



In some respects this Compound Compass may be said to resemble the ordinary pantagraph used by topographical draughtsmen; but with this most important difference, that, whereas the initial form of the pantagraph is the combination of two similar parallelograms, one within the other, as roughly indicated in fig. 1., that of Peaucellier's compass consists of two dissimilar parallelograms (fig. 2). In actual practice the links shown by dotted lines are dispensed with in both cases, but this is immaterial in point of theory. Now, if we suppose F in fig. 1 to be a fulcrum, and all the sides simple jointed links free to move round this fulcrum and round each other at their points of intersection, it is sufficiently clear, without geometrical demonstration, that as we press W nearer to F or draw it farther away, so P will move in the same direction, the distances F P, P W, bearing always a proportionate relation to each other; and if we compel W to describe any curve, P will follow a path directly proportionate to that of W. In the case of fig. 2, however, supposing the fulcrum to remain at the same point and all the conditions of linkage to be similar, it will be found that the distances F P, P W, will no longer bear a proportionate but an inverse relation to each other, that is to say, as P W increases F P decreases, and *vice versa*, the instrument being no longer a proportionator, but an invertor. This we shall hope to make clear in a few words. The annexed sketch, fig. 3, shows, in outline, the compound compass, which, like the pantagraph, is based on a combination of rods, joined by pivots at their points of intersection, and free to move about each other in any direction within certain limits. This primary system of free links Professor Sylvester expressively terms a linkage, in contradistinction to what, in technical language, is a linkwork, when, two or more points being fixed, the value of the different angles in relation to each other is definitely determined, as is, of course, the case in the Paucellier Compass, when complete and mounted.

Following Professor Sylvester's nomenclature, we will designate this peculiar form of linkwork "a mounted cell," and distinguish the different parts thus:—The parallelogram, A P B W, is the rhomb; the external arms, F A, F B, are the connectors; F the fulcrum; and F W the axis of the cell. P, the power-point, and W, the weight-point, are also called the poles of the rhomb. It must be understood that the form of the rhomb and the actual length of the connectors are immaterial, the only conditions being that the latter are equal, and that the three points, F, P, W, lie always in the same straight line whatever the position of the cell may be.

Now, if we suspend the linkage by its fulcrum to any fixed point, and imagine, for the sake of comparative reasoning, the beam, C P, to be absent, and all the joints, A, P, B, W, temporarily converted into rigid attachments, it is clear that these points will all move in concentric circles round the centre, F; loosen the joints once more, and it is equally obvious that, while A and B, being connected by inflexible links to the fulcrum, will still describe round that point the same circle as before, P is left free to move in almost any form of curve, simple or complex, and of varying radius, and that this is also the case with respect to the other pole, W. There is, however, evidently a law which determines the relative positions of the two last-named points; this law being that the nearer P is to the point F, the farther W will be from it, the diamond contracting or opening out as P is moved in any curve not concentric to F; or, in mathematical language, the path followed by W will be inverse to that of P with respect to the point F, these three points lying always in the same straight line, which we have termed the axis of the cell. If by any means, therefore, the point P be made to travel in a determinate course, the curve described by W will be equally definite and invariable. To attain this object we convert the linkage into a mounted linkwork by again adding the bar or beam, C P, to the combination, this bar forming the radius of a circle which P will describe round the fixed point C, then W will follow an inverse path, dependent for its form on the length of the radius C P, or, more correctly, on the position of the centre, C, with respect to F. Now, according to a well-known geometrical law, if the origin of inversion (the point F) lies anywhere inside or outside the circular path of P, W will itself describe another circle. If F be outside the orbit of P then the inverse circle described by W will be also external to F; if, on the other hand, F be inside the orbit, then the path traversed by W will encircle F also; but if, instead of either, the point F lies anywhere within the actual orbit, that is if the circle described by P passes through F, the inverse will be a straight line.

Turning once more to the diagram, let us suppose it to represent a rough working model of Peaucellier's concatenation. Now if the point C be so placed on the axis of the cell that the radius C P is less than half the distance F P, it is evident that the point F will fall outside the circle traversed by P, and it may be experimentally shown that W will describe the external or convex circle, of which an arc is indicated on the figure. Lengthen the radius so that it becomes greater than half the distance F P, then the orbit of P will contain F within it, and W will move in an arc of a circle concave to F, and surrounding it, as indicated by the second dotted curve in the diagram. It requires no mathematical reasoning to show, for it is self-evident, that the curves thus described will grow flatter and flatter the nearer C is to the actual centre of the line F P; and, as nature never acts *per saltum*, there must be a point in the process of change from one kind of curve to the other, where the inverse path of W ceases to be a curve, either convex or concave, when it theoretically describes two arcs of infinite radius, each looking to a centre infinitely distant—in other words, a straight line. From what has been said it is clear that this cannot happen when the radius, C P, is either greater or less than half F P, and therefore it can only be when C actually coincides with the centre of the line F P. But in this case P in its orbit would evidently pass through F, and, according to the geometrical law already laid down, the inverse described by W would then be a straight line, so that the mathematical law and the mathematical fact coincide, and the result is not merely practically but theoretically perfect parallel motion. Mechanical proof that the path of W is absolutely straight, may be obtained by taking two similar cells and joining them by the weight points. Now if either of them deviated from a straight path, so must the other in the opposite direction—"they would meet but to part like an ill-assorted couple marrying and separating at the church door;" but instead of this they will continue to move without either parting or crushing each other; following together their appointed path, neither swerving to the right nor to the left.

In addition to the forms of cell we have here described, which Professor Sylvester designates a positive cell, he has shown another, termed a negative form, to be equally possible, possessing the same functions, and having some advantages over the positive in economy of space and extent of range. In cells of the negative form the fulcrum lies within instead of outside the parallelogram, but in all other respects the construction is similar.

By his discovery, Peaucellier has placed in our hands the means of converting circular into rectilinear motion with perfect accuracy, without friction, and without any necessity for "packing," or other faulty contrivances, which have been inseparable from every system hitherto devised for the purpose of producing the same result; and the importance of this to mechanicians amounts, as Professor Sylvester has said, almost to a revolution of the principles now predominant in the application of science to the useful arts. Its use is confined neither to the highest nor the lowest branches of industry, but is common to all. It is so simple that it might be economically applied to the working of an ordinary pump handle; so powerful and perfect that the most elaborate mechanical combination to be found among our latest improvements in steam engines, is incapable of producing the same result. We may mention, as the first application of the invention in this country, that a machine, on the principle of a negative Peaucellier cell, is about to be erected in the Houses of Parliament, for the purpose of propelling a large shaft in a lateral direction, the origin of motion in this case being the wheels of a stationary engine, so that here the success of the system will be well tested.

We have been compelled to confine ourselves almost exclusively to a consideration of the invention as a mechanical power, but as a mathematical instrument the compound compass (we may name it according to the inventor's first idea now) is capable of achieving results hitherto beyond our reach, except at the cost of immense labor, and, indeed, with perfect accuracy scarcely attainable at all. Among these is the power to describe curves of almost any radius with absolute exactness, and we have only to mention how this may be made of practical service in laying out railway curves, describing sections of millwrights' work, the modelling of arch voussoirs in masonry, and the forming of moulds for fish-belly torpedoes, to suggest a hundred other cases in which it may be found equally invaluable. Torpedo making is an instance in which the Peaucellier compass would be found specially useful in superseding the cumbersome and costly appliances now necessary to insure the perfect accuracy so essential in the construction of these infernal machines.

Professor Sylvester has, by the combination of a series or train of Peaucellier cells, succeeded in producing some most interesting mathematical and mechanical results. With a mounted double cell of 13 links he is enabled to accomplish what has never been done so successfully before—*i. e.*, a perfectly accurate mechanical description of the conics, and by a linkage of three cells, of course unmounted, he constructs an apparatus for the extraction of the cube root of any number within the range of the machine. All these contrivances point to the immense—we might almost say limitless—application of the principle brought into the world by Peaucellier, but the adoption of which in England we shall owe to the enthusiastic labors of our own distinguished countryman.

TERRESTRIAL ELECTRICITY.

From "Engineering."

In the admirable remarks recently delivered by Sir William Thomson in his presidential address to the Society of Telegraph Engineers, which was printed *in extenso* in our columns, there is one subject which demands more than passing notice. We refer especially to the question of "earth currents"—the bugbear of telegraphists—coupled with other terrestrial phenomena, to which Sir William Thomson has given the name of "terrestrial electricity."

This is a subject in which the President of the Society of Telegraph Engineers has made himself pre-eminent, and his remarks deserve the fullest consideration which can be given to them. The subject embraces the magnetism of the earth, the peculiar but regular variation of the north pole, the phenomena of "earth currents," magnetic storms, and so forth. Sir William says: "That motion of the magnetic pole in a circle round the true north pole has already (within the period during which accurate measurements have been made) been experienced to the extent of rather more than a quarter of the whole revolution. It is one of the greatest mysteries of science, a mystery which I might almost say is to myself a subject of daily contemplation. What can be the cause of this magnetism in the interior of the earth?"

It might well be asked, what can be the cause of the magnetism of the earth? Is it produced by the action of electric currents, or, on the other hand, are these currents produced by the earth's magnetism? We have here a large field for inquiry, and the subject presents to our notice one of the most important points in the marvellous formation of our earth. At present it is a question of hypothesis, a pure mystery, and one to which time alone can give us the true clue.

The automatic observations taken daily at our observatories, especially at the Royal Observatory at Greenwich, show the daily variations of the magnetometers—the horizontal force, the declination, and the vertical force of the magnet—as also the daily variation of the "earth currents." The earth currents are observed by means of two wires, whose terminal points are as near as possible north and south, east and west, the point of intersection of the lines drawn from the earthplates being close to the Observatory. The strength and direction of these currents are photographically recorded, as are also the motions of the magnetometers. These results, traced by the movements of the magnets and the earth currents, will, in the future, be of incalculable value when observations have at length given a clue to the mystery of the earth's magnetism. We propose in an early number to give some account of the Magnetic Department of the Royal Observatory, where the observations of the different magnetometers and of the earth currents are taken.

It is, however, only by the effect of constant observation that we may at length hold in our hands the end of the line which shall lead us finally to the true elucidation of the question. It would be now rash even to suggest an explanation, but we may follow up the points suggested by Sir William Thomson, which will ultimately lead us on to the desired goal. The electric telegraph has now spread its arms over the whole world, and upon the superintendents and operators at the various important stations Sir William relies for obtaining such information as will prove of incalculable value. "Now, if we could have simultaneous observations of the underground currents, of the three magnetic elements, and of the aurora, we should have a mass of evidence from which, I believe, without fail, we ought to be able to conclude an answer more or less definite to the question I have put."

The President puts to the Society of Telegraph Engineers a suggestion which will ultimately bear fruit, and which we trust will soon be acted upon. It is the frequent observation during the day and during magnetic storms of the "potential" of the earth currents passing over telegraph lines, whether submarine or overhead. Simultaneous observations of the "potential" of the extremities of a line, taken at regular periods and carefully noted, is what is required.

The question arises, how can this be done? We look upon it as one of the points which will prove to the world the utility of such a scientific body as the Society of Telegraph Engineers, and whether the duty be undertaken by them alone, or in co-operation with the Royal and Meteorological Societies, it is one of paramount importance, and should be at once undertaken.

The Telegraph Engineers are eminently qualified for this duty; their members are skilled in such observations, and they are so widely scattered over the face of the earth that in a very short space of time a small army of observers could be formed for the purpose of assisting in elucidating so interesting a scientific problem. There will, we apprehend, be no difficulty in obtaining the requisite amount of observers, but the instruments of precision required for such purposes are somewhat costly, and it is on this point that the greatest difficulty will be experienced. However, by unity of action and proper representations, we do not doubt but that the instruments will be in due time forthcoming.

The observations of the "currents" which are daily traversing the earth in different directions, of varying strength, and of varying signs, require noting in a most systematic manner, and at regular periods of time. These observations, we consider, should be of two classes, primary and secondary. That is, the observatories for recording these "currents" in various parts of the world should be divided into two classes; the one special, the other general. The instruction as to time being of course universal. The general class of observations would be similar to the general type of meteorological observations, and would embrace notes taken at any telegraph station in the world. By a combined system of action, and with due representation, we believe it possible that all the various telegraph authorities, whether Government or private, would instruct such officials in their service to aid in this great work.

The observations on land lines would consist in noting the deflection on a galvanometer, the direction or sign of the earth current, and so far as can be obtained its "potential." One great difficulty has to be contended with in all land lines, and that is when a magnetic storm occurs, the strength of the "earth currents" becomes so great as to interfere most materially with the working of the line, and sometimes to entirely stop the traffic. We may instance the storm of February 4, 1872, when almost all the lines in Europe and the East were stopped. In such cases the energy of the superintendent and staff is almost entirely directed to the endeavor to get messages through, and so but little time is available for observation. But we still think that on such occasions some most important observations might be taken. Many results have been obtained from various places during some of these magnetic storms, but though from want of simultaneous observation and definite details they have been of no great scientific value, it must be admitted they possess a high scientific interest. In this general class of observation, to insure success, and to obtain valuable records, it would be necessary to issue most explicit instructions, and to supply every observing station with proper forms to be filled up, which, at stated intervals, might be forwarded to the general head-quarters.

It is from what we have termed the "special" class of observers that the greatest result may be anticipated. These observers would naturally be, from the importance of the charge already in their hands, gentlemen of acknowledged scientific skill and electrical attainments. We allude to those electricians who are in charge of the stations at the ends of the various submarine cables, which stretch nearly over the whole world.

By establishing a chain of stations from East to West at the ends of the various submarine cables, and supplying them with instruments of precision, we should obtain a series of observatories of the most important character. Starting from the East, we have Japan, Hong Kong, Port Darwin (Australia), Java, Singapore, thence Madras (where already Mr. G. K. Winter, telegraph engineer of the Madras Railway, has made some most important observations upon the regularity of the daily variation of the "earth currents"). Again, at Bombay, Aden, Suez, Alexandria, Malta, Gibraltar, Lisbon, Falmouth. We have thus a grand chain to England, and from England to America we have Valentia, Newfoundland, St. Pierre, and Boston.

The cables across the South Atlantic to the States of South America could ultimately be added. But the series of observing stations we have mentioned would present a magnificent field for observation.

The observations required would be the potential, the sign and the direction of the earth currents taken with the same regularity as meteorological observation. The instruments required for the purpose would be an accurate and delicate Thomson electrometer, and a Clark's standard cell. The electrometer could always be in constant connection with the cable, as it does not interfere in any way with the working. The standard cell would be necessary for taking the "constant" of the electrometer, which would undoubtedly vary from time to time, so that the results obtained might be noted in "volts" or units of electro-motive force, in order that the various results might be comparable.

We have mentioned a list of 18 stations, as points for observatories, but to commence with, this number might be reduced to 10; this would be necessary in consequence of the expense of a proper electrometer, one fit for the purpose. In many cases, however, the expense might partly be borne by the Submarine Company, as they would then have at their stations a most important instrument, which would be of the greatest use in testing their lines. There is a large field for the further use of such a valuable instrument as a good "electrometer," and it is really worth the while of our electricians to endeavor to make such an improvement in this form of instrument as will materially reduce its cost.

In the interest we have always shown for electrical and telegraphic subjects, we have brought this question before our readers in the hope that the admirable suggestions made by Sir William Thomson will find root, and that as their result the world may obtain such a series of facts and observations as will tend to prove not only the nature and source of "Terrestrial Electricity," but enable us at last to fathom the mystery of the "Earth's Magnetism."

GRAMME'S MAGNETO-ELECTRIC MACHINE.

By W. H. WALENN, F. C. S.

From the "Journal of the Society of Arts."

In a paper that recently appeared entitled "Cheap Electricity," Gramme's magneto-electric machine was alluded to as being one of the most likely means of obtaining this great desideratum. In that paper many of the possible applications of electric force were stated, the nature of electric power was defined, and the main difference between Gramme's magneto-electric machine and the ordinary magneto-electric machine was pointed out by means of a description of the general principle upon which each machine depends. In the present essay, it is intended to describe the action of Gramme's machine in detail, and to set forth the kind of work for which it is most applicable.

It has been said that the great advantage of this machine over all others is insured by a triple combination of circumstances, which the simple construction of the apparatus makes possible. In fact, the production of (1) a continuous current implies that (2) no heating takes place in the bearings of the machine beyond that due to ordinary friction, and that (3) the current is supplied by a minimum of steam power; for the only drawback to the full attainment of the two latter points is the reflex action of any currents that are uncollected or wasted. The almost perfect realization, therefore, of continuity, freedom from skilled attention, and cheapness of working constitute the salient points of Gramme's machine, and give it a position among electro-motors (including galvanic batteries and other magneto-electric machines) which is unique, and has hitherto been quite unattainable.

In practice, the tranformation of one kind of force or affection of matter into another kind of force, is never effected without more or less loss. In the best steam engines less than one-fourth of the heat is utilized as mechanical power; many steam engines only give mechanical power equivalent to one-tenth of the heat used in working them. The transformation of electric power into chemical work is, however, more perfect, for a single battery cell can be made to deposit 96 ounces of copper by the loss of 100 ounces of zinc; the combining weight of copper being 63.5, and of zinc 65.5, this is more than 98 per cent. of the electric power used. The change of mechanical power into electric force, by the assistance of magnetism, has been hitherto subject to the above described drawbacks, namely, the loss, neutralization, and reflex action of the electric currents, and the heating of the apparatus, and has consequently labored under difficulties from which the continuous current is free; but as no experiments have hitherto been made to ascertain how much per cent. of mechanical force has been converted into electrical force by any of the magneto-electric machines, or, to the author's knowledge, by Gramme's machine, the saving of power and of money which it accomplishes cannot yet be told.

As the facile and definite recognition of an electric current in a given conductor is highly essential to the proper understanding of the action of Gramme's machine, and as many writers on electricity have failed to describe the method of determining this point with ease and certainty, this important point of the subject will be fully set forth. Not only is it necessary to realize the direction of a given electric current in the description of electrical apparatus, but also in the employment of electric force; for instance, if the effect produced by one condition, say the forward progress along a wire, is to heat the point of junction of the two dissimilar metals, then the backward motion of the same current will cool the same junction. In one direction through a chemical solution, the current throws a metal out of the solution on to a given metallic surface; in the other direction it dissolves the metallic surface which it had previously deposited, taking it into solution. In one direction, through the coil of a bar electro-magnet that is vertical, it causes a north magnetic pole to be uppermost; in the other direction, through the same coil, the south magnetic pole will be uppermost. Even scientific men have fallen into error in describing the direction of the electric current evolved from a galvanic battery. Dr. Althaus, in the first edition of his book on medical electricity, announces the remarkable fact (or rather fallacy) "that the direction of the current is different in the ordinary voltaic pile and in the constant batteries." He further states that, "if, however, the metals are plunged into separate vessels, as is the case in the constant batteries, the direction of the current becomes different." The whole of this paragraph is rewritten in the second edition, and the fact of the direction of the current in the instrument being the same in both cases is fully brought out, Dr. Althaus having evidently fallen into error in the first instance, in consequence of the original "pile" of Volta, of the year 1800, commencing with double plates and finishing with double plates; whereas a single negative copper plate for a positive pole at one end of the series, and a single positive zinc plate for a negative pole at the other end of the series, is all that is required. Perhaps the clearest way of stating the direction of the electric current in the galvanic battery, which is the key to all other electro-motors, is mentally to take a single cell--composed of zinc, acid solution, and copper—and to conceive (for the sake of convenience) that the electric force is torn away from between the particles of the zinc plate during its solution by the acid, and that, being set free, the electric force passes across the acid to the copper plate, thence along the wire to the work to be done, and back again to the zinc plate through its conducting wire, thus completing the circuit. If now the word positive be taken to mean the state of giving out electric force, and negative the state of receiving electric force, the following assertions will be true:—The zinc is the positive plate, and the copper is the negative plate. The wire connected to the zinc plate having at its other end a plate in a solution for depositing copper, for instance, and that connected to the copper also having another plate in the same solution at a small distance from the first, the plate connected by wire with the zinc plate is the negative plate, and receives the deposit, that connected by wire with the copper plate is the positive plate, and is gradually dissolved in the solution. If simply the wires be brought from the respective battery plates, and be left free to be employed upon any work that may arise, it therefore comes to pass that the wire from the zinc plate in the battery is called the negative pole, and that from the copper plate the positive pole; for, although the current, in the battery, proceeds from the zinc to the copper, in the connecting wire and through the work to be done, it proceeds from the copper to the zinc. The kind of mental certainty to arrive at, and of figure to be formed in the imagination, in the conception of the ideas I have endeavored to illustrate, is akin to that consummated and to the figure formed mentally when describing the direction of motion of the hands of a watch. We may either say that the hands of a watch move from left to right or from right to left; in the first case we mentally take the upper half-circle by which to describe the motion, in the second case we mentally take the lower half-circle by which to describe the motion. If we always describe the motion of the hands of a watch by reference to the upper half-circle, we must say that they move from left to right; just in the same way, if we always describe the direction of a galvanic current in reference to its passages through the galvanic cell, we must say that it passes from the zinc (as the giving out or positive metal) to the copper, which is the receiving or negative metal. There is this difference, however, between the description of the motion of the hands of a watch and the direction of a galvanic current—that it is scarcely ever necessary to describe the motion by reference to the lower half-circle, but it is very often necessary, when speaking of the work to be done by a galvanic battery or any other electro-motor, to describe the direction of the current by reference to that portion of the circuit which is outside the galvanic cell, and which includes the work to be done. To further elucidate the direction of an electric current, a thermo-electric arrangement of bismuth and antimony may be taken. In this instrument the electric current proceeds from the bismuth to the antimony across the heated junction; the bismuth is therefore said to be positive and the antimony negative. In the frictional machine, generally consisting of a glass plate and a silk rubber coated with amalgam, the current (if it can be called one) proceeds from the glass to the rubber, from the rubber to the earth, and from the earth back again to the prime conductor, thence to the glass plate; the glass plate is therefore said to be positive and the rubber negative. In Armstrong's steam apparatus, called the hydro-electric machine, the issuing steam is positive and the boiler is negative; the current therefore goes from the issuing steam to the boiler, in that portion of the circuit which is internal to the apparatus.

Having stated the exact difference between Gramme's machine and all previous machines that are in practical use, in the article on "Cheap Electricity," it is simply necessary to compare the various mechanical means of applying the principle of augmentation or diminution of magnetic polarity (that upon which all ordinary magneto-electric machines depend), with the only practical means at present known of applying the principle of transition or translation in space of the same force of magnetic polarity, which is the principle of Gramme's machine.

The earliest known remark or notice which has reference to magneto-electricity is to be found in the "Monthly Magazine" for April, 1802. This states that at Vienna it was discovered that "an artificial magnet" decomposed water as well as the voltaic pile. From this point, the progress of discovery and invention divides itself into two parts, for in 1831 Faraday announced two independent facts; one was that the separation of a coiled keeper from a permanent magnet produced an electric spark in a divided portion of the coil; the other was that the rotation of a copper disc between the poles of a permanent magnet generated an electric current from the centre of the disc to the point placed between the poles of the magnet. From the first of these results sprang the magneto-electric machines with to-and-fro currents, which, by the inventive power of Wheatstone, Henley, and others, have been adapted to telegraphic work, without the intervention of a commutator; indeed, they appear peculiarly suited for that class of work in which alternate impulses are required and can be directly utilized. The result with the copper disc is connected with the theory of the Gramme machine, and never had its practical application until M. Gramme's machine was invented. Faraday evidently had a high idea of this, the latter portion of his discovery, for he remarks: "Thus was demonstrated the production of a permanent current of electricity by ordinary magnets."* Foucault searched in vain for the practical method of evolving this current; and Wheatstone neglected to publish his method of working because he did not find it practical.

In its simplest shape, the Gramme machine consists of an electro-magnet, or coiled armature, of an entirely new form, that revolves on an axis between the poles of a horse-shoe permanent magnet, the axis of

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* "Experimental Researches," vol. 1., p. 27.

revolution being exactly between the poles, and at right angles to the plane of the permanent magnet. As this electro-magnet is the main point of M. Gramme's invention, it will be well to trace its development from the copper disc of Faraday through certain successive steps. The analogy between Faraday's copper disc and Gramme's electro-magnet is not perfect, even regarding the first as the nucleus which, upon development, might yield the second; for the copper disc was mounted upon a horizontal axis, and its periphery revolved between the poles of a horse-shoe permanent magnet, the horizontal plane of which was at right angles to the plane of the copper disc, the horizontal axis necessarily being at some distance from the magnetic poles; whereas the axis of the Gramme electro-magnet or bobbin is exactly midway between the magnetic poles, and the bobbin is in the same plane as the magnet; but Faraday's arrangement was the first to show that a continuous current could be obtained by the motion of an electrical conductor near to a permanent magnet, or, as it is more distinctly described, in the magnetic field. Another discovery of Faraday's bears more directly upon the exact principle of Gramme's bobbin, although the arrangement only permits of a continuous current (in contradiction to a shock) being obtained for a limited time. About the same date as that of the copper disc experiment, in 1831, Faraday discovered that, during the introduction of a permanent bar magnet into a long hollow coil, an electric current was induced in the coil in a definite direction, and lasted for the time that the magnetic pole, so introduced, moved in the same direction in the coil. This effect is still better manifested, and the analogy with Gramme's bobbin is more perfect, if the long coil contains a soft iron core from end to end, and if this modified arrangement is moved in front of the pole of a permanent magnet, so that successive portions of the axis of the coil become opposite the pole of the magnet. The same result would be accomplished if the coil were fixed, and the magnet moved from end to end of the coil parallel to its axis and always at the same distance from the axis; but inasmuch as in Gramme's plan the coil moves and the magnet is stationary, the former supposition is more directly applicable to the explanation of Gramme's bobbin. Virtually, Gramme's bobbin may be considered as the long coil, with the soft iron core in it, bent round and joined at its extremities, so as to form a continuous annulus or ring. Not only are the extremities of the soft iron core perfectly joined so as to form a complete ring without a break, but the extremities of the insulated wire that forms the coil are soldered together so as to constitute a perfectly closed electric circuit. The axis of revolution of this ring is at right angles to its plane, and passes through its centre. The action of the poles of the permanent magnet upon the soft iron core during its revolution, is to induce two poles of the same name upon that part of the core that is from time to time in close proximity to the pole of the magnet of the opposite name; that is to say, if the north pole of the permanent magnet be uppermost, that part of the core which is from time to time uppermost, and therefore nearer to the north magnetic pole, has induced in it two contiguous south poles. In the same manner it is evident that the lowermost portion of the core, being nearest to the south magnetic pole, has two contiguous north poles induced in it. As the south pole of the core is always uppermost, and the coil revolves, the coil has an electric current induced in its upper half, continuous and in a definite direction. As the north pole of the core is always downwards, and as the circumvolutions of the coil constantly pass this pole in the same direction as they pass the south pole, the electric current induced thereby in the lower half of the coil is continuous, but in the opposite direction to that induced in the upper half of the bobbin, because the opposite magnetic pole is active in inducing this current.

Now comes the question of the direction of the electric current that may be drawn from this machine, in the consideration of which the remarks and elucidations that have already been given, especially those connected with the galvanic battery, will be of essential service. It is simplest, in the first instance, to consider the electric current in the upper half of the coil totally independent of that in the lower half of the coil. An apparatus, presently to be decribed, is applied to the bobbin, so as to collect the current at the two points in the horizontal diameter of the bobbin that separate the constantly changing upper half from the lower half; the definite direction of this current in the upper half depends upon the polarity induced in the core at its constantly changing apex (south polarity), upon the direction of rotation of the bobbin, and upon the direction in which the insulated wire is wound, whether as a right-handed or as a left-handed screw. If the ring be driven in the direction of the hands of a clock (from left to right), and the coil be a right-handed screw (proceeding from right to left), having a south polarity induced in it, the electric current will be from the right hand of the diameter of the ring to the left. If a galvanic cell be supposed to be in the place of the upper half of the ring, the zinc plate of that battery would be to the right hand, and the copper plate to the left. In the lower half of the ring the analogous galvanic cell would also have its zinc plate to the right hand and its copper plate to the left. This is seen more clearly by the reader, if he constructs a sketch according to the above description and results from the fact previously alluded to, namely, that the current from the lower half of the ring is in the reverse direction to that in the upper half of the ring. When the sketch suggested above is made, it will be realized, that if two stationary wires were maintained in rubbing contact with the metal of that portion of the coil which is constantly passing the horizontal diametrical points above alluded to, one wire being in contact with one extremity of the diameter, the other with the other extremity, these wires would conduct away both currents in the ring, and as these currents always continue in the same direction, and never change either their absolute or relative direction, there is no necessity for a commutator, or pole-changer in the ordinary sense of the term, but only for rubbing contacts. To clearly understand that both the currents are able to be collected in the way above indicated, although they are neutralized in the continuous circuit of the ring, it should be realized that, thus wrought out, the arrangement is equivalent in electric action to deriving an electric current from two galvanic cells that are virtually two halves of the same cell. To illustrate this in a lucid manner by sketching, the direction of the currents may be indicated by arrows, according to the above description, in connection with a circle that represents, in the fashion of a diagram, the centre line of the ring, the two conducting or polar wires being placed at the extremities of the horizontal diameter. As plates of a similar name will be seen to be metallically connected, if the analogous galvanic cells are placed in this diagram, it will be easily understood that the galvanic analogy is enabled to be carried as far as that, by supposing the cells to approach each other and then by removing the walls of each cell (all of which supposition may be carried out by successive sketches on paper), the arrangement is seen to be virtually the same as that of a single current proceeding from a single cell in the direction indicated by the plates of that cell.

The method of establishing the rubbing contacts merits a separate description. That rubbing contacts are essential is evident from the fact of its being necessary to take the electric current from those portions of the moving coil that successively arrive at two opposite points of a fixed horizontal diameter. This can only be done by fixed contact pieces placed respectively at the extremities of the diameter of another circle concentric with the shaft on which the bobbin rotates. To denude a portion of the coil of its insulating material, at the place where the rubbing contacts could conduct away the current (a circle of more or less breadth, concentric with the ring), would be mechanically impracticable, for the coils are of fine wire, they overlap, and they are not in their external portions at all regularly disposed, at least not sufficiently so to be treated in this manner. It is, moreover, highly necessary that the contact pieces in connection with the coil, and therefore movable, should be able to bear friction. This result is best accomplished by means of a cylindrical *frotteur* or rubber, in connection with the axis of the bobbin, the frotteur being fixed on the axis at a convenient place for the stationary contact pieces to bear strongly upon its cylindrical surface, and for the wires from certain divisions of the coil to be brought for the conveyance of the whole of the current of the machine to it. The frotteur itself consists of a cylinder of hard-wood, or other non-conducting material, driven tightly on the axis, and carrying on its surface separate and distinct rectangular plates of metal, placed at equal distances upon its circumference. The plates are securely fixed with their longest dimensions parallel to the axis of the cylinder. Although the coil of the annulus is perfectly continuous, certain offshoots or branch wires are taken from it at equal intervals to the various plates of the frotteur. There may be twelve branches, or as many as forty, according to the size of the machine and the kind of work it has to do. The stationary rubbers may consist of wheels at the extremity of standards. Each wheel is pressed, by springs or otherwise, against opposite points in the horizontal diameter of the frotteur, and its standard is furnished with a binding screw for holding the conducting wires of the apparatus. One binding screw attaches the positive wire to the machine, the other the negative wire.

Undoubtedly, the principal applications of the electric current from this machine are to the electric light in its various modifications, and to the deposition of metals in some cases from their ores. The separation of copper from its ores is waiting for a cheap electro-motor to make it a successful manufacture. The singular aptitude of Gramme's machine for manufacturing purposes on a large scale lies in its constancy as well as its continuity of action; as long as the motive power rotates the machine at the same speed, the current from it is the same in power, and the speed of rotation need not be great. There are some uses of the machine which have still to be tested; amongst them may be mentioned increasing the traction power of locomotives by electro-magnetic attractions, the firing of mines, and the treatment of iron, in a hot state, by magnetic induction.

ON THE MECHANICAL PRODUCTION OF COLD.*

The author defined the mechanical production of cold to be the removal of heat from a body without the intervention of a colder body, by a continuous circle of operations. Any arrangement for effecting this was merely a heat engine, whose temperature of absorbing heat was lower than its temperature of rejecting heat, the motive power in this state of things being negative. An air engine was the type of all refrigerating machines in which the medium used was incondensable gas. A steam engine with a surface condenser might be taken as a type of those in which this medium was a vapor or condensable gas. Harrison's ether machine was the best known of this type.

The author's attention was first directed to this subject when manager of the paraffin oil works of Messrs. Young, Meldrum, and Binney, where a large quantity of paraffin had to be extracted from the oil. To effect this it was necessary to cool the oil in which the paraffin was contained in solution, to a temperature of from 35 deg. to 40 deg., in order that the paraffin might crystallize and be separated. When, from the constantly increasing size of the works, it became impracticable to cool this oil by exposure in cold weather, an ether machine was procured, which did good service and overcame the difficulties for a year. As at the end of that time the machine was found to be too small, and as in use it not only required a great deal of care, but had been attended with several narrow escapes from fire, it was considered desirable to attain the same end without the employment of a volatile and inflammable fluid. Air was selected as the medium, and the author was requested to devise the means for making it available.

The experiments were commenced on a small scale. At first air was compressed into a receiver, and allowed to expand by driving a small engine—a plan which had been before proposed and tried, but offered little encouragement. The next trial was with an apparatus similar to Stirling's air engine, with which, after many modifications, mercury was frozen. This apparatus consisted of a cylinder of thin tin plate, and a piston of the same material soldered air-tight. The ends of the cylinder were cones, with their apices looking inwards. The lower cone was kept full of water to carry off any heat that might be formed, and into the upper one was placed the substance to be cooled. The piston was hollow, sliding nearly air-tight in the cylinder, the ends being conical, to fit the ends of the cylinder, and connected at their apices by a cylindrical opening filled with layers of wire gauze. Through this opening, when the piston was moved up or down, air passed freely from the space above the piston into the space below, and *vice versa*, traversing on its way the layers of gauze of which the regenerator was composed. The lower end

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* From a paper read before the Institution of Civil Engineers, by Alexander Kirk.

of this cylinder was connected by a pipe to a cylinder and piston, so that, by moving the latter up and down, the whole of the contained air was alternately compressed and expanded. The piston was moved by a crank, and on the same shaft there was an eccentric at right angles to the crank, by which the piston containing the regenerator was moved up and down. The crank and eccentric were so placed that while the piston was compressing the air in the cylinder, the piston containing the regenerator was at the top of its stroke, and the air in this cylinder was compressed in the space between the piston and the conical bottom containing cold water, by which the heat of compression was removed from this portion of the air. When the piston by which the air had been compressed was at the bottom of its stroke, the piston containing the regenerator was moving rapidly downwards, and the compressed and cooled air was passing through the regenerator, from the lower space into the space between the piston and the upper conical end of the cylinder. While the piston containing the regenerator was in this position the piston by which the air had been compressed moved upwards, and the air in contact with the upper cone expanded, abstracting heat from the contents of the cone, whatever they might be. The regenerator prevented heat passing with the air from the hot chamber to the cold.

As the regenerator formed an essential part of the apparatus, and much of the efficiency of the machine depended on its working properly, the author made a series of experiments to ascertain what quantity of heat would be conveyed by air through regenerators of various constructions and proportions. Two kinds were tried; one of wire gauze in layers, the air entering at right angles to the sheets, and another of sheets of metal divided into strips and placed edgeways to the current of air, which thus passed along the surface of the plates. The apparatus consisted of a cylinder, in which a piston was moved backwards and forwards, causing the contained air to pass at each motion of the piston through a hole in the cylinder containing the regenerator to be tried. One end was kept at a temperature of 212 deg., and in contact with the other there was a measured quantity of water, of which the rise in temperature showed the amount of heat that had passed with the air through the gauze. In the best results, the air, when of atmospheric density, in travelling from the cold end to the hot end and back again to the cold end, was found to have become warmed 0.0162 deg. for each degree of difference of temperature between the hot and cold sides of the regenerator; and with air of 100 lbs. pressure per sq. in. above the atmosphere the rise of temperature was only 0.00421 deg. for each degree of difference. From these experiments the author drew the following conclusions:

(1) That the efficiency of the regenerator increased nearly in proportion to the density of the air, but in a somewhat slower ratio; and that the efficiency of all surfaces for heating and cooling the air would increase nearly as the density of the air passed over them.

(2) That it was sufficient to use one layer of gauze for each 3 deg. difference of temperature between the two sides of a regenerator.

(3) That in a regenerator the surface exposed to the action of the air only was of value, the proportion of weight of regenerator to weight of air passed through it being of no value.

In the large machine as actually made, the principle of action was precisely the same as in the model. The compressing and expanding cylinder was double-acting, each end being connected with a cooling cylinder. The piston of the compressing cylinder was worked direct from the piston of a steam engine, and the pistons of the cooling cylinders were connected to each end of a beam, and were worked by an eccentric at right angles to the crank. The action of this machine was illustrated by a diagram; the motion of the pistons being represented by curves, the ordinates of which showed the volume of air in the several compartments of the machine at each part of a revolution. In these machines the air contained might be at any pressure, the efficiency of the machine and its capacity for work increasing with the pressure. The ordinary working pressure was from 100 to 120 lbs. (maximum) per sq. in. To maintain this pressure and to make up loss by leakage, there was a small compressing pump drawing its supply of air through two boxes in succession, each filled with chloride of calcium. It was necessary to keep all moisture out of the machine, as, if the air pumped in were damp, the extreme cold of the expanding air caused it to be condensed and to be deposited as snow, chiefly in the upper layers of the regenerator. Besides enabling the use of all volatile and dangerous fluids to be dispensed with, which was the object aimed at in adopting this machine at Bathgate, experience showed that but few repairs were required, owing chiefly to the absence of valves, and to the possibility of using cupped leather packings. The repairs were in amount and kind such as were required in a steam engine, and were equally within the skill of an engine fitter. The machine at Bathgate had worked night and day since the year 1864.

The author next described a modification of this machine, adapted to work with moist air, and capable of being constructed on a large scale, without the difficulties which attended the manufacture of extensive cooling surfaces in the former machine. It differed from the one just described in the corrugated plates being dispensed with, and the water or brine to be cooled, and the water to remove the heat of compression, being injected amongst the working air. Consequently the interior of the machine required no lubrication by oil, and there was no need to keep the air dry. This machine consisted essentially of two cylinders placed side by side, each containing a double acting plunger, connected to a crank fixed on a revolving shaft, at any angle between 180 deg. and a right angle, but the author preferred them to be from 135 deg. to 120 deg. apart. These cylinders were connected at each end by a large open passage, containing a regenerator, through which, on the plungers being moved, the air could pass freely from one cylinder to the other. The water to be cooled was forced in by a pump and allowed to flow down one end of the regenerators, while the water used to remove the heat of compression was forced in and allowed to flow down the other end. The water thus flowing constantly into the machine escaped through valves whose opening was regulated by a float. It was then explained by a diagram, whose ordinates showed the volume of air in each compartment of the machine at every point in a revolution, how two plungers, arranged as above, performed the function of the three pistons employed in the dry air machine, one piston moving up and compressing while the other was nearly stationary at the end of its stroke, both pistons moving opposite ways and shifting the compressed air into the other cylinder, that piston receding and expanding the air while the first piston was nearly stationary at the end of its stroke, and then both moving opposite ways and shifting the expanded air back into the first cylinder. The first cylinder was hot and the second cold, and being double-acting the same operations were performed at each end of the same cylinder. This machine was the first constructed, and might be improved; the mechanical friction was too great, and the construction of the regenerator was not what could be wished. By a rearrangement of the machine the friction had been much reduced. The regenerators now procured could not at first be obtained, and reliance had to be placed on a somewhat imperfect one of sheet brass. In the works where this machine was used these imperfections were of incomparably less importance than the power of its doing work regularly, with little trouble to any one, and with perfect safety even in careless hands.

The two machines described—the wet and the dry air machines—had each a value of their own. The dry air machine was capable theoretically of producing any degree of cold, while in the wet air machine the range was limited to about 22 deg. when using brine, but within that range was to be preferred. With one dry air cooling machine to abstract at a very low temperature the heat rejected in a second machine, temperatures might be maintained lower than any yet reached, and thus an important instrument in physical research would be put in the hands of the investigator. The great advantages of the wet air machine, which must secure its adoption in all cases where the range of temperature was limited, were that the temperatures of the air and of the water were nearly equalized; no oil was required in the cylinders, and it was not necessary to dry the air previous to its admission into the cooling cylinder. The importance of this was well illustrated by the trouble in getting ordinary enginemen to attend to so simple a matter as fuzing chloride of calcium. This elementary step from the domain of ordinary mechanics to the domain of chemistry had, particularly abroad, given more trouble than all the rest of the machine put together. After suggesting that cooling by expansion would probably be found a more effectual means of drying air than either chloride of calcium or sulphuric acid, the author, in conclusion, gave the results of three trials of these machines

(1) Of the dry air machine, made at Bathgate in 1864:—Diameter of cooling cylinders, 36 in.; stroke 2¾ in.; diameter of compressing cylinder, 15 in.; stroke 30 in.; pressure of air in one cylinder by gauge, 100 lbs. maximum, 46 lbs. minimum; pressure of air in other cylinder, by gauge, 110 lbs. maximum, 52 lbs. minimum; revolutions, 66 per minute; power spent in driving, including friction, 23 horse power; quantity of cooling water per minute, 4.3 gallons; temperature of inflow, 62 deg.; temperature of outflow, 94 deg.; quantity of brine cooled, 6.7 gallons per minute; temperature of inflow, 32 deg.; temperature of outflow, 23.5 deg.

(2) Trial of the wet air machine, June 24, 1871:—Diameter of hot and cold cylinders, 36 in.; stroke 36 in.; diameter of barrel of hot and cold water pumps, plunger, and bucket, 6 in.; stroke, 6 in.; revolutions per minute, 35; power by diagrams from steam engine, 37 horse power; power by diagrams from air cylinders, 26.3 horse power; quantity of cooling water per minute, 20.3 gallons; temperature of inflow, 63.25 deg.; temperature of outflow, 81 deg.; quantity of fresh water cooled per minute, 20.6 gallons; temperature of inflow, 61.25 deg.; temperature of outflow, 47.25 deg.

(3) Trial of the same machine in the ordinary course of its work, cooling paraffin oil at the Oakbank Works, Midcalder, December 14, 1872:—Revolutions per minute, 34; power from diagrams of steam cylinders; spent in driving, including friction, 25 horse power; quantity of cooling water, per minute, 18.55 gallons; temperature of inflow, 67 deg.; temperature of outflow, 73 deg.; quantity of brine per minute, 13.05 gallons; temperature of inflow, 37 deg.; temperature of outflow, 28.25 deg.

Unfortunately the exigencies of the work required the quantity of brine to be reduced to nearly one-half of what it ought to have been. Thus, the screens were imperfectly washed, the air imperfectly warmed, and the general efficiency of the machine was somewhat reduced. In the above experiments the water was measured in tanks erected for the occasion.

If these machines were perfect and worked without friction, the results for 1 lb. of air would have been for one revolution:

In the dry air machine: foot pounds to drive machine, 1179.993; rejected heat, 7.12 lbs. of water heated 1 deg. Fah.; absorbed heat, 5.59 lbs. of water cooled 1 deg. Fah.; temperature of rejected heat, 587 deg. absolute; temperature of absorbed heat, 461 deg. absolute.

In the wet air machine: foot pounds to drive machine, 756.359; rejected heat, 6.68 lbs. of water heated 1 deg. Fah.; absorbed heat, 5.28 lbs. of water cooled 1 deg. Fah.; temperature of rejected heat, 561 deg. absolute; temperature of absorbed heat, 476 deg. absolute.

Applying these results to the trial of the dry air machine, and the second trial of the wet air machine, as the temperatures assumed above agreed with what probably was the temperature of the air in these trials, the perfect results, without friction, etc., ought to have been:—

In the dry air machine: Indicated horse power, 7.8; rejected heat, 1,409 lbs. of water heated 1 deg. Fah. per minute; absorbed heat, 1,106 lbs. of water cooled 1 deg. Fah. per minute.

In the wet air machine: Indicated horse power, 7.8; rejected heat, 2,271.2 lbs. of water heated 1 deg. Fah. per minute; absorbed heat, 1,795.2 lbs. of water cooled 1 deg. Fah. per minute.

COMPOUND ENGINES.

By A. MALLET.

Translated for Van Nostrand's Magazine.

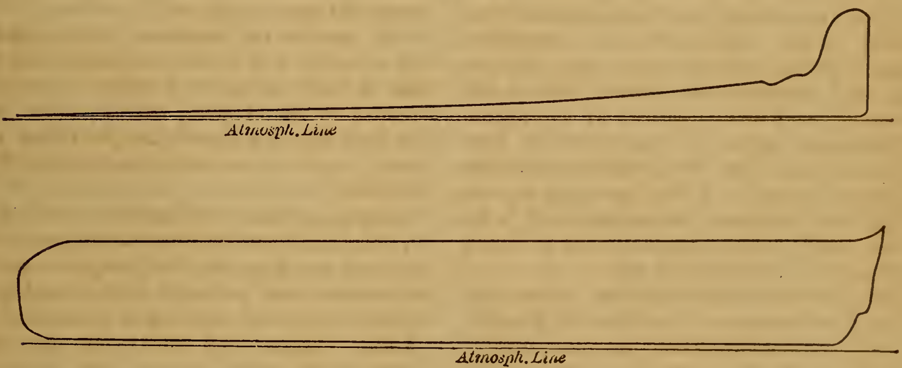
(*Continued from page* 304.)

We shall now investigate the causes of the physical superiority in the action of compound engines over those with a single cylinder.

These causes are two in number: The first, which is common to all engines of this class, is due to the fact that the difference of extreme temperatures in each cylinder is less, and that the interior condensation is much diminished. The second, which is peculiar to engines with an intermediate reservoir, is due to the partial removal of the water from the steam which held it in suspension at the time of its leaving the first cylinder; so that the water does not pass, in a liquid form at least, to the second cylinder.

For the better comprehension of these effects, it is necessary first to examine what takes place in single-cylinder engines. Suppose an engine of this kind acting expansively; the steam is admitted during, say one-fifth of the stroke. Then the piston moves by virtue of the expansion, and the pressure diminishes in a certain ratio with the increase of volume, until the end of the stroke. As the temperature of the steam diminishes with its pressure, a contraction takes place in consequence of the cooling, which acts at the same time with the expansion to diminish the pressure; and we perceive that if the steam receives no heat during its expansion, the pressures will diminish more rapidly than by Mariotte's law. But, on investigation of the action of expanding engines without cylinder envelope, we find a different condition of things. We have taken a number of indicator diagrams from a non condensing engine, into which admission took place only during very small fractions of the stroke, varying from $\frac{1}{40}$ to $\frac{1}{8}$. Besides, the actual expansions were much less because of dead space; the correction reducing the apparent expansions from 40, 20, 13.33, 10 and 8 to 14, 10.5, 8.04, 7, 6 volumes.

FIGS. 3 AND 4.



The figure (3) shows the diagram from an engine with actual expansion of 14 volumes. The initial absolute pressure being 2.75 atmospheres, the tension at the end of the stroke, by Mariotte's law, should be considerably below the atmospheric pressure. The diagram shows the contrary. The pressure, which decreases rapidly near the post, afterwards approaches the horizontal line, and at the end of the stroke is considerably above the atmospheric line. This is due to the vaporization of the water in the cylinder during the period of expansion, which furnishes a supplement of steam whose tension is added to the primitive tension.

At first it seems that it is an advantage that the work obtained is greater than that due to Mariotte's law; but we must count the cost, and it is easy to show that it costs as much or more than the work of full pressure during the entire stroke, so that all advantage of the expansion is lost.

By calculation of the area of the curve and of the mean ordinate, we shall find the mean effective tension of the steam to be 0.236 kil. per square centimetre. The cylinder has a diameter of 0.200 m., a stroke of 0.40 m., 30 strokes per minute; the work on the piston is 29.2 kilogrammetres. The volume of steam in the cylinder at the instant of closing of the admission port, dead space included, is 0.942*l.* This weighs (at a tension of 2.75 at.) 1.50 gr. per litre; that is, 1.163 gr. for 30 strokes per minute, corresponding to 4,547 per hour, or 11.65 H. P. of sensible steam acting on the piston.

If we now take a volume corresponding to $\frac{1}{10}$ of the stroke, and, assuming that the steam is in a saturated condition in the cylinder, apply to this volume the weight per litre corresponding to the observed pressure, we find at this moment in the cylinder a weight not of 1,263 gr., but of 1,410 gr.; at the middle of the course it is 4,837 gr. At the end it is still less, but at this point observation becomes more difficult because the pressure comes near the atmospheric line. We assume the figures 4,837 gr., which correspond to a sensible expenditure of 47 kilog. of steam per H. P., hourly; *i. e.*, 4 times the amount found above.

Referring to figure answering to the admission for the whole stroke, we find that the mean ordinate of mean effective pressure is 1.56 kil., giving for 30 revolutions a work on the piston of 196 kilogrammetres, or 2,615 H. P. The volume of steam which fills the cylinder at the end of the stroke is 12.56*l.*; which, at a pressure of 2.95 atmospheres, gives 18.84 gr., or 67.824 kil. hourly, or 26 kil. per H. P.

As there can be no other steam in the cylinder, we must conclude that the engine uses less at full pressure than when acting with full expansion, a fact long ago verified.

The presence of the great quantity of steam in the cylinder, can be explained only as due to vaporization during the period of expansion of the water contained in the cylinder, which is caused by diminution of pressure, and at the expense of the heat of the metal. But from what source does this water come? In the case under consideration the water was supplied by a tubular boiler; but the engine went very slow and did very little work.

As the dimensions of the boiler corresponded to a performance 15 or 20 times as great, it is difficult to admit that any considerable portion of the water was held in suspension in the steam. It was almost entirely due to the condensation at the admission port. The steam meets the surfaces, walls and ends of the cylinder, the piston and the rod, all of which are at a lower temperature, and partly condenses, while it raises the temperature of the metal. To raise 10 kilog. of metal 10 deg. requires 10 × 10 × 0.15, or 15 units of heat, answering to a condensation of about 30 grammes of steam. Hence, at the beginning of the stroke there is a certain quantity of water; it is this which vaporizes as soon as the pressure at the admission port diminishes, by absorbing the heat of the walls of the cylinder and that of the piston, a heat which is lost by escape or by transfer to the condenser. The cooled metal then demands from the steam just arrived from the boiler a fresh quantity of heat, acting as an agent to exchange between boiler and condenser. This explains the fact often noticed, that in condensing engines, having cylinders without jackets it is more difficult to effect a vacuum with complete expansion than with full steam.

It is to be observed that the elevation of the temperature of the walls of the cylinder by condensation does not take place instantaneously, any more than does the vaporization that attends expansion. Time has its part in the phenomenon. In engines of slow action the loss of heat is much greater than in those of more rapid movement. The engine in our own experiments was under the most unfavorable conditions; acting without condensation, at full expansion, slowly, and at a low pressure.

The office of steam jackets is to keep the walls of the cylinder at a constant temperature, so as to prevent the presence of water in the cylinder and the resulting inconveniences. A certain quantity of heat is lost, corresponding to the condensation in the jacket; but as the pressure in the jacket does not vary, this condensed steam will remain in the condition of water, or will be expelled by the clearing valves; it will not pass back into the state of vapor while absorbing the heat, as would be the case if it had been condensed in the cylinder. This is the true statement of the action of jackets: *they maintain the heat in the cylinder and cause condensation to take place in the jacket where the pressure is constant, and not in the cylinder where it is variable.*

The jacket does not always prevent the formation of water within the body of steam, because of very prolonged expansions due to cooling and dilatation. We shall find it possible to avoid these consequences.

The following observations are of interest:

(1) We note the little efficacy in the action of jackets of wood, felt, polished brass, etc., which resist only cooling from without.

(2) It is easy to show that little would be effected by replacing the steam in the jacket by the heated gases of combustion, as has been attempted in some engines (sometimes the interior cylinders of locomotive engines are placed in the smoke chest).

A cubic metre of steam at 5 atmospheres weighs 2,600 kil., and by condensation may lose 500 heat units per kilogramme, or 1,300 per cubic metre. A cubic metre of gas from combustion, at a temperature of 350 deg. represents 0 66 kil., giving 200 × 0.25 × 0.66=33 heat units.

To replace a layer of steam a centimetre in thickness would require a layer 40 centimetres thick, of heated gas (assuming that the conductibility is perfect), or 40 square metres to replace a square metre of heated steam.

(3) In the old engines the steam from the boiler circulated in the jacket before entering the cylinder. It is easy to see that this would cause steam to pass into the cylinders containing water in suspension, which would cause a clear loss of heat in case of expansion; then this water would remain in the jacket without disadvantage. A special pipe should always be used through which to pass the steam into the jackets.

What has been said regarding the jackets applies equally to the cylinder ends and to the pistons. The importance of regarding the latter is great in engines of short stroke, in which the diameter is $2\frac{1}{2}$ times or more than the stroke. In these engines the ends are always heated; and pistons are heated by means of grooved rods and other devices.

Nowadays cylinders and their jackets are generally of the same coating, in order to avoid complex and delicate adjustments. Hence serious difficulties in construction. Perkins, in the engines of the steamer Filga, substituted for the jacket a serpentine iron tube sunk into the cylinder. In this tube the steam circulates. This compels an increased thickness of the cylinder. But the weight need not be much greater than with a jacket, and the construction is easier.

We return to two-cylinder engines. Notwithstanding the real efficacy of steam jackets, still it is certain that there is always more or less condensation of water during expansion. This is necessarily proportional to the extreme differences of temperature to which the cylinder is subjected, as well as to the extent of cooling surfaces.

In double-cylinder engines, especially with intermediate reservoir, this difference of temperature is reduced for each cylinder. If we suppose a pressure of 5 atmospheres, corresponding to 152 deg., an intermediate pressure of 2, corresponding to 120 deg., and a final pressure of 0.50, corresponding to 81 deg., the difference in the first cylinder will be 32 deg., in the second, 39 deg. With a single cylinder the difference would be 71 deg.

We shall find that the total condensation will be considerably diminished. Suppose the ratio of volumes of the two cylinders to be 2, 5, the first being 0.78, its total cooling surface is 4.70. The volume of the large cylinder being $0.78 \times 2.5 = 1.95$, its cooling surface is 8.86. We have then

$$4.7 \times 32 + 8.86 \times 39 = 495.$$

A single-cylinder engine of the same work and the same expansion should have the dimensions of the large cylinder. In this case we have

$$8.86 \times 71 = 629.$$

The advantage in favor of the double-cylinder engine is 21 per cent. It is so real that, as mentioned before, jackets are sometimes dispensed with in compound engines, when the expansions are not great. It is possible also in engines with intermediate reservoir, which have the special advantage, that the water held in suspension at the time of leaving the first cylinder is deposited in the reservoir and does not pass into the second cylinder. It would seem that it always has been observed that the intermediate reservoir produces much water, for Zander, in his patent, mentions the use of a float valve to discharge this water. The intermediate heater vaporizes this water and makes it do work again in the large cylinder.

The following are the conclusions which we think can be drawn from our investigations:

(1) The usefulness of a steam envelope is incontestable, being greater as the differences in temperature increase, so that jackets are more advantageous for condensing than for non-condensing engines, for great expansion than for slight, for single than for double-cylinder engines. But when expansion is considerable, the jacket is not sufficient.

(2) Engines of two cylinders have a decided superiority over those with one, so that for moderate expansions, steam jackets may be dispensed with.

(3) The compound engine, which we have called the Wolff, has advantages over the ordinary Woolf engine, because the dead spaces have less influence, and because the steam that has worked in the first cylinder can be there separated from the water, so as to work better in the second cylinder. Again, the small cylinder is less exposed to interior cooling, and it is less necessary to employ the steam jacket.

These facts seem very simple, yet they are often misconceived. For example, we read in the work of a distinguished author, as follows: "The means by which economy of steam is attained, consist, while using mean or high pressures, (1) in superheating the steam; (2) in employing long expansions, either by Woolf's method, or directly. This requires, all other things being equal, less complicated apparatus, and it is considered efficient at least as regards the utilization of the steam. In land engines, where space is of little account, some builders propose to make use of expansions of 0.95 (20 volumes). In all such cases the cylinders have envelopes. But the use of jackets with circulation of steam is to be avoided."

This was written in 1866. We think that, in view of a great number of facts and of the general use of the compound engine, the author should modify his conclusions.

The Bulletin of the Industrial Scientific Society of Marseilles (1873) contains this note upon steam jackets, by Stapfer:

"Steam jackets are a costly addition, which only apparently increase the power of an engine. They seldom last more than two years, unless with the greatest precaution. Indeed, there are few engines in which they are not much obstructed. Of course, I do not refer to locomotives whose cylinders are inside the steam chest or in the smoke box, but only to return-water jackets. It is obvious that by placing the cylinder in an atmosphere of waste gases at 300 or 400 deg., a very appreciable quantity of heat can be utilized. But these are conditions seldom realized, and they belong rather to the construction of the boiler."

We can here only refer the reader to what has been said above concerning the real value of the direct action of the gases of combustion. They can be turned to account only by the aid of considerable surfaces. Those of the cylinders and the intermediate reservoir are not sufficient.

The heat of the gases of combustion has often been employed to reheat the steam in its passage from one cylinder to the other. Normand has made use of a tubular apparatus set in the smoke box. This was applied to his first engines and is found in his latest, as in the Ville de Brest and the Belgrano.

Stapfer says that jackets use too much steam; and to a certain extent without useful result, by superheating the steam at the end of its course in the large cylinder, when it is about to pass to the condenser. This objection has probably in some cases caused the suppression of the jacket of the large cylinder. Though the action of the jacket may be very efficient in vaporizing the water of condensation, especially on the cylinder walls, it is of little effect in heating the steam, the conductibility of which is very feeble. If, then, there is a superheating of steam, it occurs only in immediate proximity with the walls, and only when all the water has been vaporized. This vaporization and the effect of the jacket are of no account while the piston is driven by the steam. That the loss should be appreciable particular conditions are necessary; for example, that the escape should take place during a considerable portion of the stroke.

In engines of rapid action, the transmission of heat would not be sufficiently rapid. Stapfer seems to perceive this fact, for he says: "Steam jackets would be good for engines of slow action, in which heating takes place slowly."

The objection regarding the waste of steam by the jacket, made even when it is proven that this helps to avoid a greater waste, holds true in a degree only. But it is worth while to reduce it as much as possible. We think this can be done by employing the gases of combustion, not in directly heating the cylinders, but in generating steam to feed the jackets. The apparatus might consist of a small group of tubes at the base of the chimney where a portion of the water condensed in the jackets would collect, either by the action of its own weight or by contrivances easily adjusted.

The water would always be the same, and not coming into contact with impure substances, it would remain free from the obstructions.

The steam generated in this small boiler heated by the gases of combustion would serve only to heat the cylinders, and not at all in the direct production of motive power; so that it would be possible to supply the heat necessary for the jackets without cost.

Attempts have been made to utilize the heat held in the steam at its discharge from the cylinder by vaporizing a liquid more volatile than water, and to have this vapor act upon a second piston. By this means more work would be realized without employing much of the expansion of the first cylinder. These engines, invented by Du-trembley, who has made a great number of them, are engines of graduated pressure (*pressions étagées*). It is easy to show that the same result is obtained more simply by utilizing the expansion of the steam in successive cylinders.

Suppose a kilogramme of steam leaves the first cylinder and enters the ether condenser at 80 deg. or at one-half an atmosphere. This steam can supply 550 heat units and will vaporize about 3.5 kil. of ether at 3 atmospheres of pressure, or 440 litres of vapor. These cannot be in the ether condenser less than an atmosphere of resisting pressure; for the boiling point of ether is 38 deg.; so that expansion cannot be more than 3 atmospheres to 1.

The work of the ether cylinder will be

$$0.440 \times 3\ (1 + e \log.\ 3) - 1.32 \times 1 = 1.45.$$

If, instead of using the steam to vaporize ether, expansion is effected in a second cylinder, nearly up to the condenser pressure, it could be raised from 0.5 to 0.2 or 2.5 volumes; even supposing the most unfavorable conditions, as a tension of half an atmosphere at discharge from the first cylinder; which would imply a previous considerable expansion.

A kilogramme of steam at half an atmosphere, represents 3.200 mc.; hence the work would be

$$3.200 \times 0.5\,(1 + e \log.\ 2.5) - 8 \times 0.2 = 1.47.$$

The work is theoretically the same as that with ether; but in fact it would be more considerable, and it is obtained more simply, without the help of a dangerous fluid, without complicated vaporizers and condensers, and other disadvantages. It is but a slight advantage that the ether cylinder would have a volume of 1.32, while that of the compound engine has a volume of 8.

A disadvantage in the use of ether is, that though the boiling point is low, its tension in the condenser is high, so that what is gained in one way is lost in another. Besides, its vapor has considerable density.

Combined vapor engines have given good results when comparison was made with engines in which steam has been badly utilized. They gave splendid results when their consumption was 1.50 kil. per H. P., as compared with 2.25 to 2.50 kil. of steam engines. Nowadays, a kilogramme per H. P. is realized with much simpler means. Still it would not be fair to forget that ether engines have rendered important service by familiarizing us with the use of surface condensers. The majority of these engines, after the use of ether was given up, have been worked as steam engines with the use of ether vaporizers and condensers as surface condensers.

V. Our investigations naturally lead to the question whether by increase of pressures and expansions indefinite improvements may be realized; or, as Siemens has said in his report to the Institute of Mechanical Engineers, whether, in the course of ten years, we may not hope for a reduction of 50 per cent. in consumption.

We must first say a few words of the methods of determining the useful effect ot our engines. It is hardly necessary to remark upon the superficial and crude nature of the results generally given concerning the performance of a steam engine, results indicating the amount of fuel burned per hour, the unit of work upon pistons and cranks.

We often see the consumption indicated with the minutest accuracy in figures containing two or three decimals; and this without the slightest mention of the kind of fuel employed, though it is well known that the heating powers of combustibles vary greatly, so that an engine can run more economically with 2 kil. of one sort of fuel than with 1.50 kil. of another. What value have such reports?

Suppose the kind of fuel accurately stated; still the figure of consumption per H. P. has no scientific value because it confounds in one estimate a set of distinct elements which should be separately examined, as the amount of steam and its use, the work of the generator and that of the engine.

This is clear. Take for example an engine that uses 10 kil. of steam per H. P. This is supplied by a boiler set under very bad conditions, vaporizing only 5 kilog. of water per kilog. of fuel. The consumption is 2 kil. hourly per H. P. Another engine may use 20 kilog. of steam, but if it is fed by a generator that very perfectly vaporizes 10 kilog. of water per kil. of fuel, the gross result of consumption per H. P. will also be 2 kilog. There is no apparent difference between the two.

The careful examination of this question is of great interest, for it leads to an important result: the conclusion that, if we give to the better of the two engines the better generator; or, if to the generator is attached an engine that utilizes the steam in the best manner, then, instead of 2 kilog., we should have 1 kilog. of consumption, or 50 per cent. economy.

That steam engines have been gradually brought to their present perfection, is due to the minute and careful analysis of the physical phenomena which convert the heat of coal into a motor force. It is easy to indicate the necessity of the separate study of the elements of the steam engine, but not easy to represent this separation in practical experiments. But it is possible, in land engines, to take a satisfactory account of the interior action of the apparatus, both by observation of the weight of fuel burned and of water converted into steam, and by measuring the work on the shaft by the Prony brake and the work upon the piston by the indicator. But in the case of great marine engines, the weight of fuel and the work upon the pistons are the only elements easily measured. Results must be obtained by comparison or by approximation, somewhat coarse, it is true, but yet of great interest, and with much probability of correctness in them, because of the great number of facts we have at hand.

In marine engines, the expenditure of steam—and therefore the performance—is generally estimated by what is termed the weight of sensible steam in the cylinders; that is, the weight as shown by the indicator diagrams. As we have seen, this indication is often illusory. Though in engines in which the condensation in the cylinders is limited by suitable conditions of action, it may approach the real figure, so as to give results accurate enough in practice, still, in other cases, it gives results of no possible value.

This weight of sensible steam in the cylinder, which we shall call P′, differs from the weight P′ of water actually vaporized in the boiler, because it does not take into account the loss of steam by leakages, condensations in the tubes or at the entrance to the cylinder, by dead spaces, etc. But it also differs from the weight p of steam theoretically necessary for a given pressure and expansion; because it takes into account the various restrictive elements of the motor force, such as the reduction of pressure between the boiler and the cylinder, the phases of distribution, lead, compression, actual expansion, obstruction, etc. Hence, in general

$$P > P' > p.$$

Further on we shall find apparent exceptions, for which we should be prepared.

We shall first determine, for various pressures and expansions, the theoretic weight of the vapor p consumed hourly to produce the work of a H. P., on the piston.

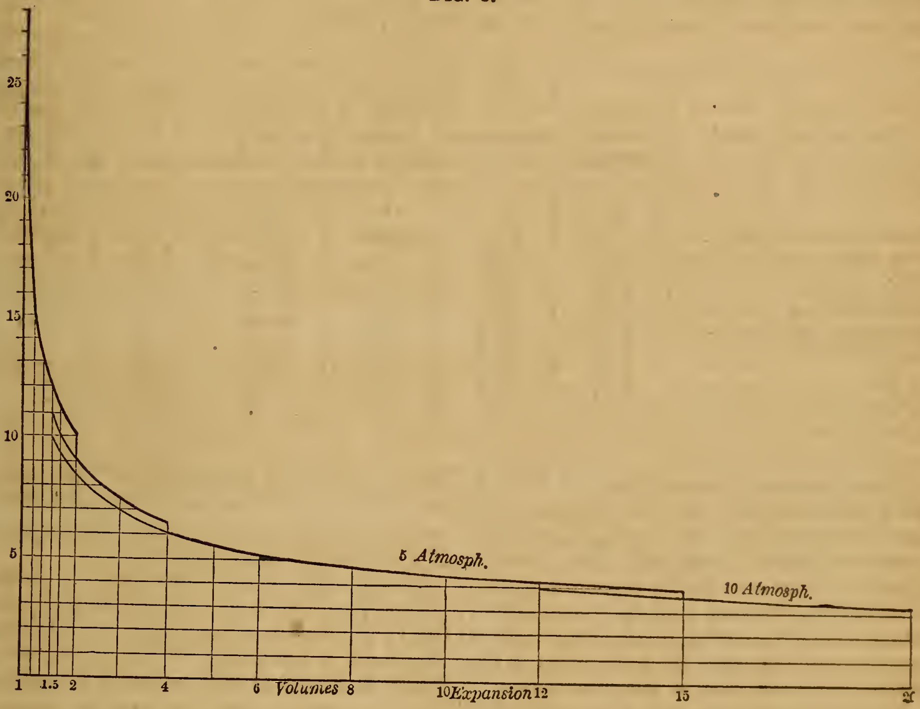
The following table gives the values of p for several kinds of marine engines. The figures are *theoretic*, being obtained from the formula for the work of steam. Only the resisting pressure in the condenser, estimated at 2 metres of water, is taken into account.

The figure illustrates the results graphically.

EXPANSION.	MODE OF ACTION.			
	Low pressure engines, 1½ atmosphere boiler pressure.	Mean pressure engines, 2½ atmospheres boiler pressure.	High pressure engines, 5 atmospheres boiler pressure.	Very high pressure engines, 10 atmospheres boiler pressure.
Volumes.	kg.	kg.	kg.	kg.
1.2	14 50	.....	.....	....
1.33	13.33	12.10	.....	....
1.50	12.20	11 05	.....	....
2.	.....	9.16	8.31	....
2.50	.....	8.10	7 34	....
3	.....	7.42	6.75	....
4	.....	6.50	5.90	....
5	.....	.....	5 40	....
6	.....	.....	5.05	....
8	.....	.....	4.60	....
10	.....	.....	4 25	3.92
12	.....	.....	4.05	3.70
15	.....	.....	3.80	3.50
20	.....	.....	.....	3.25

The weight P′ of sensible steam in the cylinders shown by the indicator, should be more than the theoretic weight p, since the steam loses in various ways during its work. Of these losses, some are shown by the diagram, others are not sensible and introduce so many errors into the results that they are really not of practical use. They are almost exact enough for engines in which the condensation in the cylinders is a minimum. But they answer only when comparison is made of engines whose actions are nearly identical. Useful results may be obtained respecting the distribution of the steam and the resistances in passages, pipes, etc.

Fig. 5.



The rate of the expansion normally employed ought to regulate the disposition of the parts of the engine; an engine constructed for a certain expansion will not work so well with a much greater expansion. The reasons have already been given; we add experimental confirmation as given in a table from "Engineering," in which is shown the weight of sensible steam in the cylinders of compound engines, each working with 3 deg. of expansion.

Number of engine.	1.		2.		3.	
Expansions	5 6	10	6.55	13.75	7.4	16 74
Absolute pressures	5.4 k.	5 k.	5.4 k.	5 k.	5.2 k.	4 7k.
Velocity of piston	1.77 m.	1.49 m.	2.175 m.	1 75 m.	1.98 m.	1 56 m.
Weight of sens. steam in cyl. per hour and per h. p.	6.38 k.	6.43 k.	6.61 k.	6.43 k.	6.84 k.	7.29 k.

This table shows that the increase of expansion in the same engine increases instead of decreasing the consumption of steam. It is true that in the examples cited, action with full expansion corresponds to the least pressures and velocities of the pistons, and that there should result a diminution of useful effect of steam and an increase of losses by interior condensation. But the advantages due a greater expansion would more than compensate if it should act under normal conditions, precisely what it does not do. With an engine set to expand 5 or 6 volumes, expansions of 10, 12, or 15 volumes can be had only by a corresponding reduced admission into the first cylinder, so that one falls upon some of the inconveniences of single engines, to say nothing of the losses of pressure due to the intermediate spaces and passages of double cylinders.

We call attention to the ratio between the weight of sensible steam and that of the theoretic in order to warn the reader of an error which has escaped the notice of many persons. We annex a table.

Designation of engines.	Absolute boiler pressure.	Expansions.	Theoretic weight of steam per h. p.	Weight of sensible steam, P′, per h. p.	Ratio. $\frac{p'}{p}$	Consumption of fuel per h. p.
	k.		k.	k.		k.
Woolf stationary engine..	5.15	10	4.25	5.60	1.30	0.95
Aigle, imperial yacht.........	2.70	1.66	10	8.87	0.89	..
Abeille....	2.12	1.54	11.30	10.50	0.90	2.25
Frigate, 250 h. p..	2.47	1.54	11	11.10	1.00	1.75
Steamer, 600 h. p....	2.10	2	9.50	10.79	1.14	1.78
Swift Steamer, 900 h. p.... ...	1.98	1.66	10.70	12.00	1.12	1.64
Compound engines, 1.........	5.40	5.60	5.20	6.38	1.22	....
Id. 2.........	5.40	6.55	4.90	6.61	1.35	....
Id. 3.........	5.20	7.40	4.70	6.84	1.57	....
Hercules, tug................	2.17	1.66	10.35	13.00	1.25	....

The first thing remarked in this table is that, while for most engines the sensible is greater than the theoretic weight, in other cases the ratio is one and less. Again, where this ratio is small, the consumption is increased, showing that the economy of steam is only apparent, there being no reason for supposing that the generation in the boiler is any less than in the other cases.

The conclusion is that we must not judge of the economy of an engine by the low rate of apparent expenditure of steam.

The explanation of this somewhat paradoxical result is simple, depending entirely upon what has been said above of the action of certain single engines without jackets. The vaporization during the period of expansion of the water condensed in the cylinders, produces a total work greater than that which corresponds to the apparent weight of water in the cylinder; although this work is often much less than that which is due to the amount of steam from the boiler. Besides, the steam in the dead spaces expands during the period of expansion. The error is due to the fact that the diagram indicates only the presence in the cylinder of the vapor in a gaseous condition during the period of admission; that is, a part only of the steam which has entered the cylinder, which leaves it at the end of the stroke. One cannot be too careful in avoiding the errors which result from a superficial examination. We insist upon this point because it seems to have escaped the notice of writers, the majority of whom say nothing about it.

Though the value of the weight P′ is not of importance, it is otherwise with the quantity P, which represents the amount of water vaporized in the boiler. Unfortunately the direct measure of this quantity is attended with certain difficulties, and is possible only in a few cases. Especially in marine engines, where results are not to be obtained by experiment, we are obliged to deduce the weight of the fuel by assuming that we know the weight of water vaporized per kilogramme of fuel (an element which can be determined for a given fuel and generator), or to calculate it approximately in terms of p or P′.

In the first case, *i e.*, when P is deduced from the weight of fuel burned, it is necessary to take into account the water taken up by the steam, which tends to increase apparently the vaporization, and also to take into account the loss of heat by *extraction* when the boilers are fed with water containing salt. It is important to do this when comparison is made of engines condensing by injection with engines provided with surface condensers.

In land engines it is easier to measure directly the water introduced into the boiler, an element which should be determined as accurately as possible in experiments. In the example cited, of a Woolf beam engine, the weight of water vaporized per H. P. was found to be 6.5 kilo.; hence we have the following values:

P	6.50 k.	1.53	1.00
P'	5.60	1.30	0.85
p	4.25	1.00	0.653

At sea, where boilers of the same kind and action may be assumed to have almost identical vaporization, P may be estimated from the amount of coal burned. For example, we may assume a vaporization of 8 kil. of water per kil. of fuel, which is not too high an estimate for good coal, even with salt-water feed. The value of $\frac{P}{p}$ may then be deduced, and a sufficient number of data would determine the value of P in terms of p.

An examination of results from a very great number of engines, gives a mean ratio of 1.55—nearly the same amount as that obtained by direct measurement; so that we may safely assume the value of $\frac{P}{p}$ between 1.5 and 1.6. In some cases, it is true, this ratio is 1.3, and even 1.25; in others, it is 2. We must conclude that in the first case the vaporization is a little more than our assumed figure (8 kil.), and that, in the second case, there are special causes of the loss of steam. We do not give 1.5 or 1.6 as an exact coefficient; but we think it may be admitted as a mean value, and employed in *projets.*

A question occurs. The 50 or 60 per cent. which should be added to the theoretic weight of steam expended per hour to produce a H. P. of 75 kilogrammetres upon the piston, represents losses of all kinds, from boiler to condenser. Can these losses be reduced by suitable precaution and care in the construction of engines? The answer is, that it is to these reductions, and not to increase of expansion and tension, that we are to look for future improvements. It would be a great gain to reduce $\frac{P}{p}$ to 1.40 or 1.33.

We find that there is little to gain in the way of expansion; and possible increase of tension is very limited, on account of the difficulties in disposition of boilers, and those attendant upon too high a temperature. It does not seem possible, theoretically, to expend less than 3.50 kil. of steam; assume, rigorously, 3.25 kil., answering to a tension of 10 atm. and an expansion of 20 volumes. We suppose the most conditions perfectly favorable.

For the ratio $\frac{P}{p} = 1.50$, the weight of water to be converted into steam per H. P. is about 4.90 k. This, with a vaporization of 8.5 k. per kilogramme of fuel (with surface condensation), would lead to a consumption of 0.58 k. per H. P. per hour.

With the ratio $\frac{P}{p} = 1.33$, there would be the same result, with a theoretic weight of steam 3.70 kil., answering to an expansion of 12 volumes only to a pressure of 10 atmospheres; an expansion much easier to effect, and requiring dispositions much less complex than expansions of 20 volumes. Were it possible to combine the reduction of the ratio with the minimum expansion, the consumption would be reduced to 0.500 k.

So far, we have sought only for improvements in making use of the steam, without regard to the method of its generation. It is obvious that progress may be made in this direction, and that it may be considerable. For example, if the production of steam per kil. of fuel could be brought to from 8.5 k. to 10 k.—a result not hopeless—the expenditures would be reduced to 0.85; becoming 0.50 k., in the first case, and 0.43 in the second.

Such results will certainly not be obtained without great efforts; but we may reasonably hope to approximate them with means already at our disposal, while, in our opinion, it would be chimerical to attempt directly to reduce consumption by means of radical modifications in the generation and use of steam.

An objection is often urged, that it is indeed possible to make economic engines, but on condition of employing costly and cumbrous devices, too heavy and bulky.

A steam-engine consists of a generator to produce the motive vapor, and an engine to put it to use. The weight of an engine is in a certain measure controlled by its proper disposition, especially with regard to rapidity of action, while the weight of the generator necessarily depends only on the generation of steam and the pressure at which the steam is produced. The weight of the generator includes the weight of the boiler and the water it contains

Boilers may be referred to various elements; as to the unit of power, the unit of grate surface, the unit of heating surface, etc.

For our purpose the unit of weight of fuel consumed is convenient; but care must be taken not to draw from the figures conclusions which they do not warrant. It is obvious that the weight of the boiler, per kilogramme of fuel, will be less in proportion to the amount of fuel burned every hour, and hence, that this weight will vary with the activity of combustion, and will not in any way give the measure of economical use of fuel and metal; hence the considerable differences in boilers of the same type. The true method of determining the efficiency of generators, with respect to weight, is to refer to the kilogramme of steam—if only one could get direct data of this element; but as this must generally be deduced from the weight of fuel, it is as well to make direct reference to it.

We prefer, in all cases, to refer to the weight of coal burned, rather than to the square metre of grate surface. This would be rigorously possible only in case the boilers burned the same quantity of coal; but as the consumption may vary within wide limits without a corresponding sensible change in the production of steam answering to a kilogramme of fuel, we may ask, what is the real value of such a mode of estimation?

With the above reservations, our method of measurement will permit us to take account of the possible results of a given kind of boiler.

The following table contains results corresponding to various kinds of boilers.

DESIGNATION.	Weight in kilogrammes of coal per hour.			KIND OF BOILER.
	Of empty boilers.	Water.	Of full boilers.	
	k.	k.	k.	
North, Crampton	15.2	5.8	21	Locomotive.
North, 4 cylinders	24.6	7.4	32	Id.
North, moyennes Creusot	33.5	9 5	43	Id.
Francoise I^{er}	28	20	48	Cylindric tubular. cast steel.
Machine compound	58	17	75	Cylindric tubular.
Steamer, 900 h. p	49	26	75	Regulation.
Steamer, 800 h. p	31	22	53	Id.
Ulster	36	26.5	62.5	Tubular return flue.
Tasmanian	43	32	75	Id.
Sphynx	68	41	109	With galleries.
Eldorado	55	50	105	Id.
Roanoke	76	42	118	Martin.
Brooklyn	65	51	116	Id.
Donawerth	35	24	59	Lamb and Summers.
Colombo	75	55	120	Id.
Guayaquil	61	51	112	Spiral, Randolph and Elder.
Hirondelle	31	2	33	Belleville.

Because of the tendency toward high pressures, it is probable that there will be a return to that type of locomotive boilers, which easily support pressures of 10 atmospheres, and which being fed with fresh water will give rise to no difficulty; always, with the condition of their having sufficient draft. It is clear that one of the first steps in improvement of marine boilers must be the adoption of means for producing an energetic draft. These boilers weigh at most, 43 kil. per kil. of fuel consumed; in some cases, 20 to 30 kil.; 40 kil. may be taken as an average. Another solution may consist in the use of the Belleville boilers, which, on the Hirondelle, gave 33 kil. But this figure should probably be increased on account of the fact that the coal was not well utilized. At any rate, we must admit the existence of boilers which do not weigh, water included, more than 40 kil. per kil. of fuel consumed hourly. A boiler of this kind feeding an engine expending only 0.5 k. per H. P., would weigh only 20 kil., water included, for the same unit.

Observing that the lighter boilers in combination with the most economic engines weigh 60 kil. per H. P., and the total, 80 to 100 kil., and more, we see that an economy of weight of 40 kil. at least, and possibly from 60 to 80 per H. P. is realized.

This weight, referred to an engine which, for a velocity of 60 revolutions per minute, weighs 80 to 100 kil. per H. P., represents a bonus of 50 per cent., which would allow an increase of the weight of the cylinders and their accessories; for it must not be forgotten that the excess of weight due to the increase of expansion affects only those parts on which the steam acts, and not the parts that transmit motion; while the parts that relate to condensation follow the reduction of the weight of the boilers. It is easy to verify this assertion rigorously. The development of the power in every steam-engine corresponds to a certain volume described by the pistons in a unit of time. This volume varies with the tension of the steam, the degree of expansion, and the efficiency of action of the engine.

The volume for a unit of power is found by multiplying the volume of the cylinders by twice the number of revolutions in a unit of time, and dividing this product by the indicated power. It can also be directly obtained without knowledge of the dimensions of the engine, by dividing the value of a unit of power by the mean effective pressure on the pistons, as shown by the indicator.

The volume, V, per H. P. is

$$\frac{\pi r^2 \, 2 \, c \, n}{P};$$

P being the power; but as $P = \pi r^2 \, 2 \, c \, n \, p$, p being the mean effective pressure of the steam, we have $V = \frac{1}{p}$.

It is more convenient to refer this to the minute. We have calculated for a great number of engines of all kinds.

In certain engines, in which builders have thought that they obtained lightness, they have sacrificed the performance; the volume per H. P. and per minute falling to 0.250 cm., and even to 0.200 cm. In most engines of ordinary action with tension at 2.5 k. and 2.75 k., this volume is 0.300 m. c. to 350 m. c.

In the compound engines, mentioned by Bramwell, acting with full expansion, but at higher tensions, we find 0.385 cm. and 0.658 cm., as extreme values; the mean being 0.450. In engines with less expansion the values range from 0.300 to 0.400.

We infer that for the same number of revolutions, the volume of the cylinders will be increased only in the ratio of 1 to 1.5, an increase of volume corresponding to an increase in weight from 1.25 to 1.30. But suppose the weight rises to 1.50 or 2, so as to take into account the presence of jackets and the increase in section of slides and ports. In stamping engines, nowadays much used, the average weight of the cylinders with pistons and slides is 30 per cent. of the whole engine; it follows that, in this case, for a weight of 100 kil. per H. P., we should have 130 kil., or an increase of 30 kil.

We have seen that the minimum economy for boiler is 40 kil. We infer that a reduction of boiler-weight due to better use of steam, will permit the increase in weight of cylinders and pistons required by increase of expansion.

THE ELEMENTS OF COST OF RAILROAD FREIGHT TRAFFIC.*

By O. CHANUTE, C. E.

The subject of determining the cost of railroad transportation is seemingly a very simple one. So simple that to one unacquainted with the subject, it doubtless appears capable of easy solution, after a brief investigation. And, indeed, when, at the close of the year, the report of a railway company is published, it is comparatively an easy matter to reduce its whole business to an average number of passengers and of tons of freight transported one mile, and to ascertain approximately the average charges and cost of each. We thus obtain, however, only averages and nothing more. It is when we attempt to look further into the subject, and inquire why this average cost varies upon different lines, and what are its various elements, or to ascertain what profit has been made upon a particular class of the traffic, and what portion has been done at a loss, that we find very considerable intricacy and complication.

It is found, not only that this cost varies greatly upon different roads, in consequence, as we shall see, of local peculiarities, but that even upon the same road, it varies materially from year to year and from month to month. A comparison, by the reader, of the monthly earnings and expenses of al-

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most any railroad, will exhibit the fact that their ratio is far from being uniform; that the cost of carrying a passenger or a ton a mile varies 30 and 40 per cent. between the different months, and that in some cases the whole of the traffic is actually worked at a loss during some portion of the winter months.

The ultimate purpose of the investigation, which led to the remarks from which these notes are taken, being to ascertain the cost of particular operations upon a single road, it was thought necessary first to ascertain whether the division of the various elements of cost had been assumed correctly, by comparison of several roads. The present object, however, being only to indicate what those elements are, and the manner in which they burden the traffic differently upon the several roads, the present paper will be confined to a discussion of those elements, to the pointing out of their numerous combinations, and to such general deductions as seem to spring therefrom.

And first it may be stated that the problem of separating the various elements of the cost of railroad traffic, is probably incapable of exact solution with our present knowledge. The various expenses of which they are composed are combined with each other in so many different operations, that it is very difficult to separate them, so as to ascertain the cost of any particular class of traffic with mathematical certainty. We may approximate to it, however, and thereby gain clearer ideas on a subject which we will find to be very intricate.

Even the preliminary step of separating the cost of passenger from that of freight traffic is found difficult and unsatisfactory. Not only are many services incidental to each performed by the same agents, and there is great uncertainty as to what proportion of the maintenance of the way and works should be charged to each, but there is great diversity in the mode of keeping the accounts on different roads, and the basis furnished by the companies themselves is found upon examination to be arbitrary and somewhat unreliable. For the present, however, the figures have been taken as returned, merely making such corrections as seemed obvious, and the apportionment will be made from this.

Indeed, so complicated does the subject become, upon even a slight examination, that railway managers are very loath to commit themselves to positive statements as to the cost of particular portions of their traffic, and much of the reticence which has recently been sharply criticised during the discussion which has been going on in the public prints on this subject, is no doubt due more to an unwillingness to put themselves on record concerning many points which are by no means clear even to themselves, rather than to any disinclination to enlighten the public.

Table I., prepared from the Reports of the Engineer of the State of New York, shows the variations of charges made, and the cost per ton per mile, upon seven of the railroads of this State, during the last ten years, as well as the varying ratio of the cost of operating to the total expenses. It exhibits not only that the cost has been four times as great on some roads as upon others, but also that it has materially varied from time to time upon the same road; so that, for instance, had the average rates of charges prevailing in 1863 been maintained until 1865, when the war had raised the cost of labor and materials, six out of the seven roads would have been operated at a loss.

In order to account, if possible, for the cause of the difference of the cost per ton per mile, upon these several roads, an analysis has been made of their expenses for the year ending on the 30th of September, 1872. We thus obtain, it is true, only averages resulting from many different operations for each road, but we may be able to draw some inferences from them. Table II. shows the cost of transporting freight for 1872 on those roads, under seven general elements of cost, reduced to four common standards (such as could be obtained from the reports), under the heads of cost per ton per mile, cost per mile operated reduced to equivalent single track, cost per mile run by freight trains, and cost per ton transported. If, upon examination, there appears to be any uniformity in any one element of cost, under any one head of the division, it would be considered probable that this element operated alike on the different roads, and that the particular head under which the coincidence occurred was probably the best common measure of comparison. It will be found, however, that the resulting burden imposed by each upon the traffic, differs widely upon the different roads.

The division of the elements of cost, adopted in the classification, is as follows:

1. That which is here termed "Roadway charges," and which consists of the repairs and renewals of the earth-works, masonry, ballast and wooden portions of the roadway—such as cross ties, bridges, buildings, fences, etc. The repairs of earthworks, masonry, ballast and cross-ties, have been obtained by distributing under this head one-third of the amounts charged to "Repairs of road-bed. except cost of rails." Taxes are also included in this account, and it may fairly be considered as a fixed ratable charge, independent either of the volume or character of the traffic; representing in a great measure the wear and deterioration from the action of the elements, and proving more or less of a burden, per ton per mile, in proportion to the business.

2. The "General expenses" comprising the expenses of general management and incidental contingencies. To be strictly accurate. this account should also include the cost of soliciting for and obtaining business, but as this cannot readily be separated from the amounts reported for "Agents and clerks," the whole of the "Contingencies" account has been included as an offset. This varies somewhat in proportion to the volume of the trade obtained, as well as with the length of the road, but seems quite independent of the distance the traffic is to be carried. It may in most cases be considered as an arbitrary charge of so many cents per ton obtained.

3. "Station service," comprising the items termed "office expenses," "agents and clerks," "loading and unloading," and "watchmen and switchmen," in the official reports, and covering the cost of handling and billing the freight. This varies nearly in proportion to the tonnage handled, but is quite independent of the distance it may be carried over the road. It may be considered as a specific or arbitrary charge per ton, to be pro-rated over the number of miles the goods are conveyed.

4. "Track repairs," which includes the surfacing of the track, and the repairs and renewals of the rails, spikes, and joint fastenings. This varies in some measure, but not in direct ratio with the tonnage transported, and the speed at which it is carried. It is greatly affected by the character of equipment placed upon the road, as well as by the permanence of its construction, and its peculiarities of climate and soil. In the absence of more accurate information on this subject, its best measure is probably the miles run by trains.

5. "Car service," embracing the lubrication, repairs and renewals of freight cars. This varies most nearly with the mileage made by the cars, but the time required to make a trip, unload the car, and return it to the general service, becomes an important component, and seriously increases the cost of local traffic.

6. "Train service" may be said almost to alone represent the transportation proper. It consists of the wages of the "conductors and train men," "enginemen and firemen," "fuel," lubrication, water service, and the repairs and renewals of the locomotives. This alone varies both with the tonnage and the distance it is carried, and alone can correctly be compared for different roads by reduction to tons transported one mile. Its cost upon each is affected by the character of the gradients and curves, which limit the maximum train which can be taken over the line, the proportion of empty cars which must be hauled in consequence of the preponderance of tonnage in one direction, the cost of wages and fuel, and in the case of new roads, by the impossibility of securing full loads at all times for the trains which it is desirable to run regularly.

7. The "Insurance," which mainly consists of the loss and damage accounts, and which is dependent upon the value or perishable quality of the articles carried.

Having thus distributed the expenses according to these seven different elements, and constructed the comparative tables, we are enabled to take up each division in detail, and by comparing the resulting charge per ton per mile as deduced from specific expenditures, whether it be referred to the standard of cost per mile operated, or per mile run by freight trains, or per ton transported, to inquire in what manner, and to what extent, each element forms a charge upon the general traffic, and helps to swell the cost of the whole. This analysis can only be followed by a close and frequent inspection of the table, and although, no doubt, irksome to the general reader, is yet necessary to an understanding of the very complex relations which the expenses bear to each other.

An examination of the table thus constructed at once discloses differences in cost, which no possible theory as to relative economy or efficiency of management can account for It is seen not only that like operating expenditures upon different roads, whether referred to cost per lineal mile or per mile run by freight trains, impose very unlike burdens upon their aggregate traffic per ton per mile, but also that the character of that traffic makes a very great difference in the cost of transacting it.

Thus, the Rome, Watertown & Ogdensburgh R. R., which has spent but $2,670.70 per mile operated, upon its freight business, shows a cost of 2.641 cents per ton per mile, while the Erie Railway, which has expended $8,212.58 per mile, or over three times as much, shows but a cost of 1.037 cents per ton per mile, or less than one-half as much. The Rensselaer and Saratoga R. R., which has run its trains for $1.42 per mile, yet finds the cost 2.306 cents per ton per mile, while the New York Central R. R., which has run its trains for $1.35 per mile, finds the cost but 1.043 cents per ton per mile.

These differences illustrate the influence on cost, of the total volume of business done. It is seen at once that some elements of cost are in the nature of fixed charges, and neither materially increase nor diminish, whether a large or a small business be done. That others again are specific or arbitrary charges, which are nearly constant, whether the traffic is to be conveyed a long or a short distance; and again, others increase with the business, but not in direct ratio to it; while of those which increase in strict proportion per ton per mile, the cost is probably not over one-third of the whole. One effect of this is to burden those roads which do a small business with a much higher cost than those which have developed a large traffic. There are certain expenses which must be incurred to keep the road running, and they prove less or more onerous, as the tonnage is large or small.

More important still as affecting the cost, is the character of the traffic. The road making the best showing in the table is the Syracuse, Binghamton & New York. The cost for 1872 was but 0.704 cents per ton per mile, and by reference to Table I., it will be seen that it transported freight for two years, at a cost of 0.55 per ton per mile. Yet this road has expended this year but $3,273.74 per mile of road, while the New York & Harlem R. R., which has expended but $4,531.88 per mile, exhibits a cost five times as great, or 3.635 cents per ton per mile. The New York Central, on the other hand, has expended $8,127.72 per mile operated, and its cost is 1.043 cents per ton per mile. So that we see that it is not alone the doing of a large business which cheapens the cost, by distributing the fixed charges over a greater number of tons, but also the character of that business which may require more or less looking after or incidental expense.

Comparing more in detail the Syracuse, Binghamton & New York R. R., and the New York & Harlem R. R , which exhibit the two extremes in cost per ton per mile, we note that certain of their expenses per mile operated are substantially the same. The roadway charges, the track repairs, and the insurance, practically agree. They aggregate $1,731.74 per mile, in the case of the former road, and $1,662.15 per mile in the case of the latter; yet they impose exceedingly unlike burdens per ton per mile. It is in the other elements that the great saving occurs on the S., B. & N. Y. R. R. The general expenses are only one-quarter as much per mile operated, and less than one-fifteenth as much per ton per mile as on the Harlem R. R. The station service is less than one-half as much per mile, and imposes a burden only one-tenth as great. The car service and train service are only about one-half as much per mile, and become a charge of only about one-sixth as much per ton per mile, so that those expenditures which are specifically the same on these two roads, not only differ greatly in the result per ton per mile, but those expenses which are variable are much greater in the one case than in the other. The explanation is, not only that the one has a larger, and the other a smaller relative traffic, but that the former road does a through, and the latter a local business; and that the first mainly transports coal, and the second merchandise. It will be well, therefore, to examine each element of the cost separately, and to inquire how and to what extent it burdens the traffic.

First, as to the "roadway charges," we notice a remarkable uniformity per mile of road operated, in the first five of the seven roads in the table. They have each expended about $800 a lineal mile, in replacing perishable material, and maintaining their works, and yet this cost has charged their traffic from one-tenth to six-tenths of a cent per ton per mile in proportion to the greater or less volume of business done. On the two last roads, which have expended less than the others (perhaps because it was not necessary that they should fully make the wear good for that year), the burden per ton per mile is, nevertheless, about three times as great as upon the road which has expended the most. Although part of the wear of wooden structures is due to the action of the trains, yet the greater part of it is caused by exposure to the weather. As this proceeds slowly, it is not necessary to renew an equal portion every year, and the amount expended will vary on each road in different years; but it will be noticed from Table I., that the yearly cost per ton per mile varies most widely upon the roads with the lightest business, probably in consequence of periodical renewals.

It may here be stated, that since making up Table II., the writer has had reason to believe that the proportion adopted of one-third of "repairs of road-bed" for the roadway charges, is somewhat in excess of the truth, and that a sum of about $600 or $700 a year a mile would probably cover the general cost of this element; but whether $600 or $800 per mile of road, the amount is a fixed charge, in no way affected by the volume of business, but burdening it more or less, according as it is large or small, and therefore very onerous to new roads with light traffic. These may perhaps evade the charge for a time, while everything is new, but the wear and deterioration is constantly going on, and sure some day to call for fresh expenditures, either from current earnings or from capital.

The burden imposed by "general expenses" is partly fixed and partly arbitrary. That is, there are some expenses which must necessarily be incurred in managing the line, and some which increase with the business, but not in proportion to it. As we should expect, therefore, the table exhibits great variations per ton per mile, while there is some correspondence in the columns in which it is given per mile operated and per ton transported. It is seen also to be affected by the character of the traffic, in the case of the Syracuse, Binghamton & New York R. R., whose business evidently requires very little soliciting or managing expense. Although its percentage to the other operating expenses is small, it may form, in the case of the long thin lines recently built in the West, an important element of the cost of the light traffic which they may expect for some time.

The "station service" imposes a charge which is much the same, whether the article goes a short or a long distance over the road. For four out of the seven roads, it is seen to amount to about 32 cents per ton transported, irrespective of distance; and a table will hereafter be given to illustrate how this charge alone may cause the cost to vary from 4 cents a ton a mile, to about half a cent a ton a mile. In fact, it is clear that the cost is the same for loading and unloading, checking and billing the freight, whether it is transported over the road 10 miles or 1,000.

We notice, however, some anomalies in the table. Thus station service on the Syracuse, Binghamton & New York R. R., is but 4 cents a ton transported; while on the New York & Harlem R. R. it is 35 cents a ton. This is explained by the fact, that while the cost per ton per mile, and per ton transported, is made up from the total number of tons carried, yet a part, in some cases a very considerable part, is received or delivered loaded on the cars, either in the interchange of business with other roads, or as being of those classes of goods which are loaded and unloaded by their owners. Turning, therefore, to the report of the S. B. & N. Y. R. R., we see that it carried 533,355 tons, of which 28,126 tons were reported as "of the products of the forest," presumably lumber; and 442,764 tons of "other articles," presumably mostly coal. This leaves but 62,465 tons to be handled, while the amount charged to "loading and unloading," amounts to $14,362.19, or 23.4 cents per ton of miscellaneous freight. On the Harlem R. R., on the other hand, there are but 170,779 tons reported as of "products of the forest" and "other articles," out of 377,537 tons transported, so that it is presumed there were 206,758 tons to be handled, at a cost of $41,817.55 for "loading and unloading," or 20.2 cents per ton. A similar calculation for the Erie Railway gives a cost of 25.8 cents per ton handled; so that the road which actually did its work the cheapest, finds this expense the greater burden, in consequence of the peculiarities of its traffic.

We come here upon an important cause of difference of cost of transportation between different lines. It is found not only

TABLE I.

Average Freight Charges and Cost per Ton per Mile on Railways in New York for Ten Years, as stated in State Engineer's Report.

YEAR.	NEW YORK CENTRAL.			ERIE.			LAKE SHORE AND MICHIGAN SOUTHERN.			SYRACUSE, BINGHAMTON AND NEW YORK.			NEW YORK AND HARLEM.			RENSSELAER AND SARATOGA.			ROME, WATERTOWN AND OGDENSBURG.		
	Average charge.	Average cost.	Road operated.	Average charge.	Average cost.	Road Operated.	Average charge.	Average cost.	Road operated.	Average charge.	Average cost.	Road Operated.	Average charge.	Average cost.	Road operated.	Average charge.	Average cost.	Road operated.	Average charge.	Average cost.	Road Operated.
	cents.	cents.	per cent	c'ts.	c'ts.	p. cent.	cents.	cents.	per cent.	cents.	cents.	per cent	cents.	cents	per cent	cents.	cents	per cent.	cents.	cents.	per cent.
1863.......	2.38	1 55	62.79	2 09	0.9	61.51	2.78	1.40	62 43	1 37	0.55	42 89	3 38	3.27	60.72	5 25	3.52	65 00	2.92	2 14	52.37
1864.......	2.72	2.00	71.91	2.33	1.45	66.27	3.29	2.10	60.45	1 29	0 55	41.55	5 55	4.90	75.78	6 85	3.95	49.59	3.28	2.67	55.32
1865.......	3.31	2 52	77.87	2.76	1.99	70.69	3.29	3.13	69.67	1.49	1 57	89.88	6 37	5 68	74.69	6.89	5.55	64 60	4 13	4.16	69.17
1866.	2.92	2.07	75.49	2.43	1.65	72.58	3.45	2.71	67 30	1.48	0.92	65.85	5 88	4.10	59 70	7.28	5.49	70 81	3 68	3.43	65.83
1867.......	2.53	1 89	76.20	2 04	1 47	72 18	3.41	2.87	77 38	1.59	0 88	56.02	7.23	4.87	56.60	6.90	5.27	72.80	3.74	2.99	55 72
1868.	2.59	1.64	64 24	1.92	1.35	77.51	3.46	2.63	78 07	1.53	0.89	62.16	7.62	5.78	64.31	....	....	.....	3.58	3.24	74 82
1869.......	2.21	1.30	58.09	1.60	1.17	79.29	2.83	1.58	68.73	1.92	1 50	74 47	7 32	4 88	65 44	2.81	2 06	67.67	3 70	2.84	62.35
1870.......	1.86	1 15	63.36	1.38	0 98	74.62	1.59	1.04	62.93	1.42	0.76	58.34	6 57	4.45	62 21	3.95	2.65	59.63	3.75	2 92	64.12
1871.......	1.65	1 01	61.80	1.43	1.01	71.06	1.46	0 97	66.70	1.61	1.24	75.83	6.91	4 92	60.64	3 74	2.98	72.02	3 82	3 19	68.19
1872.......	1.59	1.04	64.29	1.53	1.04	68.55	1.34	0.95	69.99	1.42	0.71	54.68	6.14	4.34	60 19	3.27	2.31	65.45	2.93	2.64	75.49

TABLE II.

Analysis of the Cost of Transporting Freight on various Railroads for the Year ending September 30th, 1872.

	New York Central.	Erie.	Lake Shore and Michigan Southern.	Syracuse, Binghamton and New York.	New York and Harlem.	Rensselaer and Saratoga.	Rome, Watertown and Ogdensburg.
Total freight earnings	$17,258.768 20	$14,737,251 50	$12.030,409 00	$556,091 03	$1,560.376 80	$1,013,853 09	$702,769 67
Total freight expenses...... .	10,648.937 14	9,859,207 80	8,397,736 73	265,172 64	764,844 10*	679,228 07	592,895 56
Total miles operated............	1,310.2	1,200.5	1,198.	81.	168.77	181.	222.
Average through tons‡..........	779,201	791,927	740,278	464,689	125,405	162,717	101,134
Average distance carried	232 34	170.86	209.10	70.57	55.73	52.88	66.73

COST PER TON PER MILE.'

Roadway	cts. 0.107	cts. 099	cts. 0.113	cts. 0 172	cts. 0.614	cts. 0.334	cts. 0.408
General expense	0.023	0.039	0 028	0.008	0.126	0.109	0 125
Station service	0 136	0 187	0.158	0 062	0.624	0 320	0 365
Track repairs	0 231	0.191	0.204	0 190	0.687	0.635	0 576
Car service	0 137	0.145	0 130	0.058	0.371	0.158	0 364
Train service	0 397	0 353	0.303	0.203	1.180	0.735	0.768
Insurance	0.012	0.023	0 011	0.011	0.033	0 015	0.035
Totals	1.043	1.037	0. 47	0 704	3 635†	2.306	2.641
Total ton miles	1,020,908,885	950,708,902	886,853,169	37,639,618	21,039,166	29,451,790	22,451,836

COST PER MILE OPERATED.

Roadway	$831 20	$786 65	$835 93	$802 21	$765 23	$544 93	$412 58
General expense	182 08	306 43	206 21	39 40	157 42	176 64	126 38
Station service	1,060 38	1,477 73	1,170 53	286 42	778 57	520 17	369 12
Track repairs	1,802 15	1,516 67	1,508 54	881 79	856 01	1,034 22	582 35
Car service	1,062 97	1,143 51	964 94	271 10	462 87	256 50	367 77
Train service	3,093 00	2,798 19	2,241 76	943 07	1,470 87	1,196 29	777 29
Insurance	95 94	183 40	81 89	49 74	40 91	23 89	35 26
Totals	$8,127 72	$8,212 58	$7,009 80	$3,273 74	$4,531 88	$3,752 64	$2,670 70

COST PER MILE RUN BY FREIGHT TRAINS.

Roadway	$0 13.77	$0 10 50	$0 14.83	$0 21.57	$0 32 45	$0 20.67	$0 26.73
General expense	0 03.01	0 04 08	0 03.66	0 01.06	0 06.68	0 06 70	0 08.18
Station service	0 17.56	0 19.71	0 20.77	0 07.70	0 33 02	0 19.73	0 23.91
Track repairs	0 29.85	0 20.22	0 26 76	0 23.72	0 36 30	0 39.23	0 37.73
Car service	0 17.60	0 15.25	1 17.12	0 07 29	0 19.63	0 09.73	0 23.83
Train service	0 51.22	0 37.31	0 39.78	0 25 36	0 62.37	0 45.38	0 50.36
Insurance	0 01.59	0 02.44	0 01.45	0 01.34	0 01.74	0 00 91	0 02.29
Totals	$1 31.60	$1 09.51	$1 24.37	$0 88.04	$1 92 18	$1 42 35	$1 73 03
Total freight train miles	7,911,257	9,004,051	6,752,291	301,200	397.985	477,157	342.654

COST PER TON TRANSPORTED.

Roadway	$0 24.78	$0 16 97	$0 23.71	$0 12 18	$0 34.21	$0 17 70	$0 27.23
General expense	0 05.43	0 06 61	0 05 85	0 00.60	0 07 04	0 05 74	0 08 34
Station service	0 31.62	0 31.86	0 33.20	0 04.35	0 34 80	0 16.94	0 24.36
Track repairs	0 53 74	0 32 72	0 42 79	0 13.39	0 38.27	0 33 60	0 38.42
Car service	0 31.69	0 24.67	0 27.37	0 04.12	0 20 69	0 08.34	0 24 27
Train service	0 92 23	0 60 37	0 63.59	0 14.32	0 65.75	0 38 87	0 51.29
Insurance	0 02 86	0 03 96	0 02.32	0 00.76	0 01.83	0 00.77	0 02.33
Total	$2 42.35	$1 77.18	$1 98.84	$0 49.72	$2 02 59§	$1 21.96	$1 76 24
Total tons carried	4,393 9[illegible]5	5,564,274	4,223,434	533,355	377,537	556,931	336,440

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* Additional freight expenses on Harlem for city transportation by horses ......$148,919 23, making total ...... $913,763.

† Additional cost per ton per mile on Harlem for city transportation by horses. cents 0.708, making total ......cents 4 343.

‡ Ton miles divided by miles of road reduced to equivalent single track.

§ Additional cost per ton transported on Harlem, for city transportation by horses....$0 39.45, making total....$2 42.04.

that the cost of loading and unloading, checking and billing goods, is independent of the number of continuous miles which they are transported over the line, but also that this arbitrary charge varies greatly upon different roads, in consequence of the nature of their business, and the proportion of it which requires handling. This may go far to explain the general prosperity of the coal roads, which, while they have been enabled to obtain very nearly the same rates as other lines, have been put to far less expense in the handling of their tonnage and management of their business.

While, therefore, the character of the traffic on each road compels a certain expense for station service, the length to which it is to be hauled governs the resulting cost per ton per mile. To illustrate the manner in which this element alone varies the cost of the traffic, the following theoretical table has been constructed on the basis of the cost for 1872, on the New York Central, and the supposition that while the cost of station service remains the same per ton, all the other expenses vary in proportion to the train miles.

TABLE.

SHOWING *the effect of arbitrary charges for station expenses upon the average train of* 130 *tons. The station expenses being assumed at* 31.62 *cents per ton handled, and all the remaining expenses at* $1.1704 *per mile run by train:*

miles cost.		*cts per ton per mile.*
10	$\frac{130 \times 0.3162 + \$1.1704 \times 10}{130 \times 10}$	= 4.062
20	$\frac{130 \times 0.3162 + \$1.1704 \times 20}{130 \times 20}$	= 2 481
50	$\frac{130 \times 0.3162 + \$1.1704 \times 50}{130 \times 50}$	= 1.533
100	$\frac{130 \times 0.3162 + \$1.1704 \times 100}{130 \times 100}$	= 1.216
200	$\frac{130 \times 0.3162 + \$1.1704 \times 200}{130 \times 200}$	= 1.058
232	$\frac{130 \times 0.3162 + \$1.1704 \times 232}{130 \times 232}$	= 1.037
500	$\frac{130 \times 0.3162 + \$1.1704 \times 500}{130 \times 500}$	= 0.932
1,000	$\frac{130 \times 0.3162 + \$1.1704 \times 1,000}{130 \times 1,000}$	= 0.932

The above, however, is for the average train of 130 tons, which is thus small in consequence of the short runs consequent upon local business. If beyond 200 miles, therefore, we assume that the trains consist of 24 loaded cars, or 240 tons, the cost becomes:

miles cost.		*cts per ton per mile.*
200	$\frac{240 \times 0.3162 + \$1.1704 \times 200}{240 \times 200}$	= 0.645
500	$\frac{240 \times 0.3162 + \$1.1704 \times 500}{240 \times 500}$	= 0.551
1,000	$\frac{240 \times 0.3162 + \$1.1704 \times 1,000}{240 \times 1,000}$	= 0.519

If, however, upon arrival at their destination, there is not enough return tonnage to load more than 10 of these cars, and the remaining 14 must be hauled back empty, the cost of the return tonnage is as follows:

miles cost.		*cts. per ton per mile.*
200	$\frac{100 \times 0.3162 + \$1.1704 \times 200}{100 \times 200}$	= 1.328
500	$\frac{100 \times 0.3162 + \$1.1704 \times 500}{100 \times 500}$	= 1.255
1,000	$\frac{100 \times 0.3162 + \$1\ 1704 \times 1.000}{100 \times 1,000}$	= 1.202

It has here been assumed, that all the expenses, except station service, vary in proportion to the miles run by freight trains. This is in excess of the truth. We have seen that "roadway charges" and "general expense" cannot so vary, being mainly controlled by other circumstances; and if we now turn to the column of track repairs in the table, we find that it varies in cost from 20 to 39 cents per mile run by trains, and a further inspection shows considerable variations in cost between the different roads, under all four of the standards adopted, and indicates that the cost does not vary in direct ratio to the business done. Thus, while the Syracuse, Binghamton & New York R. R. has expended $881.79 per mile operated for track repairs, the resulting charge is 0.19 of a cent a ton a mile; and the Rome, Watertown & Ogdensburgh, which has spent but $582.35 per mile operated, nevertheless finds the charge 0.57 of a cent a ton a mile. In general terms, the three roads of lightest traffic in the table, find the cost of track repairs per ton per mile a burden about three times as great as the other lines.

The wear upon the track is produced by three elements: 1st, the locomotive; 2d, the cars; and 3d, their contents. It is, moreover, affected by the speed, and the gradients and curves. It cannot, therefore, be expected to be in any constant relation with the contents of the cars, or the tonnage of the road, except so far as this dictates the character of the trains which must be run, the proportion of empty cars which must be hauled to provide for the business, and the full or partial loads for the cars, or for the locomotives, as a through or a local traffic predominates.

It is believed by the writer that a very large part of the wear and destruction of iron rails is due to the action of the locomotives. The exigencies of the service having led to the modern practice of placing upon driving wheels weights which approximate closely to the crushing point of iron, the locomotive alone, probably, does more mischief to the rails than the rest of the train. If this be true, it would follow that roads with a heavy traffic cannot afford to lay any rails but steel in their tracks, while it is probable that many lines now laid with iron, whose business is yet to be built up, cannot afford to run the heavy locomotives which most of them are provided with, and that they would save large future renewals by exchanging them for lighter engines. It will be noticed that track repairs alone amount to about 20 per cent. of the cost of transporting freight, so that the importance of selecting the very best material for the track becomes at once apparent. It is chiefly from this, in connection with improved methods of car and train service, that future cheapening of transportation is to be expected.

The unsatisfactory result of the analysis of "track repairs," contained in the table, may result from the fact, that as renewals of rails are made at periodical intervals, some of the roads may have expended more or less than just enough to make good the annual wear. In order, therefore, to obtain results of value, the comparison should be extended over a series of years. For the present, however, we may consider the analysis as indicating that the charge imposed by track repairs is not in direct ratio, either with the miles operated or with the train miles, nor yet with the tons transported one mile. It will also vary over different parts of the same road in consequence of curves, grades, variety of soil or character of traffic, so that it is not probable that it has the value of a constant charge of cost per ton per mile, either upon different roads or even upon different parts of the same road.

A comparison of the cost of "car service," per mile run by freight trains, shows a range from 7 cents to 24 cents per mile run. This may partly be caused by the difference in gradients upon the road, or the character of their locomotives, thus limiting the maximum train which may be hauled. We see, however, that while the cost was 19.63 cents per train mile on the New York & Harlem R. R., and this imposed a charge of 0.37 of a cent a ton a mile on the traffic, on the New York Central, where it was 17.60 cents per train mile, it imposed a charge of but 0.14 of a cent per ton per mile. The table shows considerably lower cost on roads doing a through, than on those wholly confined to a local traffic. This evidences the value of the component of time in this item of the cost; a car frequently requiring as much time to go to a station 10 miles distant, to be unloaded, reloaded if possible, and returned, as to carry the same load 300 miles; or that, as stated in the Report of the Massachusetts Railroad Commissioners for 1872, "wheels earn money only while they are in motion."

The cost of car service is also dependent upon the proportion of empty cars which the service requires to be hauled. It has been shown, while treating of station service, that if a return load can be obtained for only 10 cars out of 24 (a not unusual proportion on most of the roads tabulated), the cost per ton per mile of their contents will be more than doubled. This again indicates the smaller cost of through, as compared with local business, it being far more easy to obtain a return load promptly from a terminal than from a local station. Indeed, it is probable that were a stream of through traffic, say of one million tons a year, thrown upon the Harlem road, the cost per ton per mile on that line, which is now 3.63 cents, would at once be reduced to about one-half that amount, so that it might cheapen its charges to all its patrons.

It is to be regretted that the reports to the State Engineer do not give the mileage made by freight cars, as this would furnish an excellent basis of comparison. It might, perhaps, be obtained by multiplying the train miles by the return giving the average weight of freight trains, were the latter correct; but they have been so evidently guessed at, as to possess no value.

When we take up the "train service"—the transportation proper, we expect to find at least some uniformity of cost between the different roads, some regular element of expense, and some solid ground on which to base a claim, that their charges shall be uniform. We refer to the table, and we find instead, that the cost varies per ton per mile from 0.203 of a cent on the Syracuse, Binghamton & New York R. R., to 1.18 cents on the Harlem R. R.; or if we examine it by train miles, that it costs from 25 cents to 62 cents to run a train a mile. In order to account for this, the table on the next page has been made up of the cost, in detail, of running a freight train a mile upon the different roads for the year ending September 30th, 1872.

We see that while the repairs of engines have been pretty uniform, there are large differences in the cost of train hands, and especially in that of fuel. On the Central it is twice as great, and on the Rensselaer & Saratoga nearly three times as great, as upon the Erie, in consequence of their respective distances from the coal fields. The difference in cost of train men is to be attributed partly to variations in wages, but more particularly to the peculiarities of the road and traffic, which require a certain number of men to manage the trains, or to assist in handling the local freights at way stations. The same differences will be found to exist, though in a less degree perhaps, over parts of the same road, especially if some portions are worked as branches and some as main line, and it would seem to follow that if strict regard to cost were had in adjusting the charges, they would have to be different for similar distances on the same road and its branches, in accordance with the character of the gradients, peculiarities of traffic, distance from fuel supply, etc., etc.

Cost of Freight Train Service per Mile.

	New York Central.	Erie.	Lake Shore & Michigan Southern.	Syracuse, Binghamton, & New York.	New York & Harlem.	Rensselaer & Saratoga.	Rome, Watert'wn & Ogdensburg.
	$	$	$	$	$	$	$
Conductors and brakemen .	0.0540	0.0931	0.0688	0.0251	0.2187*	0.0316	0.0780
Enginemen and firemen........	0.0850	0.0889	0.0795	0.0318	0.1093	0.0832	0.1078
Fuel........................	0.1822	0.0873	0.1487	0.1103	0.1524	0.2363	0.1983
Oil and waste...	0.0167	0.0131	0.0146	0.0130	0.0222	0.0166	0.0098
Repairs of engines.............	0.0946	0.0797	0.0832	0.0623	0.1128	0.0837	0.1000
Repairs of tools (half of total)...	0.0045	0.0045	....	0.0027	0.0039	....	0.0055
Water.	0.0091	0.0037	....	...	....	0.0024	0.0042
Incidentals.	0.0661	0.0028	0.0030	0.0084	0.0044	....	....
	0.5122	0.3731	0.3978	0.2536	0.6237	0.4538	0.5036

In every case, moreover, it will be noticed that the train service amounts to but about one-third of the total expense per ton per mile. Taken in connection with the car service, it is scarcely one-half of the whole, and the cost of these two elements varies from 33 cents to 82 cents per train mile, the roads of largest business varying from 53 cents to 69 cents; while the total cost of operating is from 88 cents to $1.92 per mile run by freight trains. Thus the transportation proper, which almost everyone has in mind when discussing railroad charges, costs but about one-half of the cost of the total service rendered to the public. The other expenses are in some degree fixed or arbitrary charges, or they do not vary with the distance to which the goods are conveyed, and burden the business more or less in proportion to its volume or character.

As to the "insurance," or losses incurred on goods in transit, it seems surprisingly small. It scarcely amounts to 2 per cent. of the whole expenses, or probably to about one-tenth of 1 per cent. upon the value of the articles carried. Perhaps a comparison for other years would make a less favorable showing than that selected as the basis of the table.

One important element has remained thus far entirely unnoticed, and nothing has been said about the interest upon the capital invested in the road and its equipment. This is as legitimate a charge upon the traffic as the cost of running the trains, and it must be covered by the profit charged upon the various shipments. In apportioning these profits, it becomes necessary, not only to consider the varying cost of each particular class of shipment, its volume, the expenses it occasions, the bulk or space it

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* This item is so greatly in excess of every other, as clearly to indicate a discrepancy in the method of keeping the accounts.

occupies in the cars, and the risk incurred from its perishable properties, but also to use sound judgment as to its comparative value, and the amount of profit it will bear, so as to adjust the burden of transportation where it will least be felt.

It is well understood by railroad managers that the maximum of aggregate profit is by no means coincident with high charges. Every reduction of rates brings out for transportation more and more of the bulky and cheap commodities, and permits their shipment at a profit. This again cheapens the average cost of the whole by spreading the fixed charges, and those which do not increase with the traffic, over a greater number of tons; but as, in the meantime, the railroads must pay their operating expenses, and, if possible, interest on their cost, and as the business is not capable of indefinite extension, the adjustment of rates becomes a delicate operation, which requires careful experimenting in order to ascertain the rates which at any given time will yield a maximum of profit.

The universal tendency of rates in this country has hitherto steadily been downward. They sometimes have had to be raised on particular articles, but it has so invariably been found that those lines proved most profitable which developed the largest tonnage, by adjusting the rates so as to admit of the shipment of cheap articles, that it is deemed good policy to make the charges just as low as experiment proves to be prudent. The owners of new railroads, therefore, have generally been content to wait some years for full returns upon their investments, in order to promote the development of the country and of a large tonnage. But, as a compensation, they have collected more than the legal interest, whenever the growth of traffic has enabled them to obtain it.

It thus appears from this imperfect analysis of the table, which, it must be remembered, merely contains the average results of the very numerous and dissimilar transactions carried on upon each road during the year, that railroads do very much more than merely to transport the traffic which is intrusted to them. They furnish the road and rolling stock, and keep them in repair, and they load, unload, and insure the goods, in addition to carrying them. Some of these expenses have to be incurred whether a large or small business is done; many are independent of the distance which the article is transported, and others again are regulated by the character of the traffic. The cost varies with the season, with the character of the business, the value of the goods, and with the volume of tonnage which the year's crop, or prices in distant markets, brings forward for shipment, and it not unfrequently happens that a railroad knowingly transports a crop out of its tributary country at a loss, in order to furnish its patrons with the means of purchasing their annual supplies, and thus furnish profitable return tonnage for the line.

It will be seen that there is no term of comparison more fallacious, to apply to individual cases or particular shipments, than the average cost per ton per mile. This cost not only varies between the different roads, but it also varies greatly on the same road, either for different distances, or for the same distance over different parts of the line and branches. It varies with the class of goods, which requires more or less handling, and it varies even on the same goods, between the same stations, if empty cars are required to be hauled in one direction or the other. The transportation proper, including car service, is but about one-half of the whole expense, and even this varies with the cost of wages and of fuel. Railroad managers, therefore, in fixing rates to be charged, must estimate and weigh, as well as they can, the average cost of a great many different operations and contingencies, and make many attempts before they can ascertain the exact rates which will give the most profitable volume of trade, and the best returns upon the investment.

It would seem to follow, therefore, that the claim which is sometimes made, that charges for short distances shall be in proportion to those for long distances, is not founded on justice, and that tariffs cannot be made uniform, either upon different roads, or for like distances on the main stem and branches of the same road, under dissimilar circumstances of traffic. Neither can the rates be made permanent as to time, for although, doubtless, they should be changed far less frequently than they are, the cost is dependent upon so many varying elements, that a fair rate one year may be either insufficient or extortionate the next.

Even the claim, much better founded, that a higher rate shall not be charged for an intermediate than for a through distance, may be unjust in practice; the extra handling required, the furnishing of empty cars, or the time lost by demurrage, may make the cost greater for the short than for the long distance. It should be stated, however, that it is believed to be good economy, as well as sound policy, not to make a higher charge from an intermediate than from a terminal station, and that the most ample notice should be given of proposed changes in the tariff, which should be uniform in its application. The cost in the majority of cases is no greater, and the ill-feeling which is sure to be engendered by the contrary practice, more than offsets any resulting profits.

It follows, also, that until experience and discussion shall enable us to understand the subject better, the making of a freight tariff is, and must be to a great extent, a tentative and experimental process, which cannot as yet be governed by any fixed mathematical rules. When, therefore, a freight tariff has been adopted upon a road, no matter upon what theory of the probable cost it has been based, it is straightway found necessary to modify it, either in part or by giving special rates, in order to conform with the particular circumstances of the case. As various communities prosper or retrograde, as certain articles increase or diminish in supply or in demand, changes have to be made in the rates in order to adjust them to the new relative importance or cost of the business.

To one unacquainted with the subject, these changes in the tariff seem, and some in fact are, arbitrary and unjust. It is perhaps from this very process of adjusting rates to cover a variable cost, which it must be admitted has not always been wisely or honestly done, that the great dissatisfaction at present existing with the railroads in the West originated a dissatisfaction which has led to legislation likely to be as tentative and experimental as the tariffs it seeks to control. In spite of this legislation, the result of this analysis of the cost upon the New York roads, renders it not improbable that the tendency will be in the future towards even greater diversity in charges than now exists upon roads in different parts of the West. Some of them are not now earning enough to meet their operating expenses, to say nothing of future renewals or returns upon the investment, and if they are ever to become profitable, they will be led to raise their freight rates if they can. This, however, does not wholly depend on the will of the managers. It is regulated by competition, and by the charges which the goods to be moved can afford to pay; so that the result of advancing the rates, upon many roads which have been built, would be to drive away or destroy the small amount of business which they now enjoy.

A country is enabled to sustain a railroad, pretty much in the ratio of the tonnage of its annual exportable products, and this determines, therefore, the distances apart at which it is most profitable to build them. This, in an agricultural section, varies with the crops which experiment shows it most profitable to raise. Thus in the cotton States, a single railway car carries off the product of 44 acres, assuming an average of half a bale per acre, and the roads are built about 60 miles apart. In Illinois, the proximity of the lakes makes it profitable to ship corn, which only requires the product of 7½ acres, at 50 bushels to the acre, to load a car, and the roads have been about 20 miles apart. In a region growing wheat, a car would carry off the annual product of 22 acres at 15 bushels to the acre, while in a pastoral country, it would require the product of 40 acres in cattle, or of 50 acres in hogs, to furnish a single car-load. As population proceeds westward, therefore, and engages in the raising of those products of greater concentrated value, in proportion to their bulk, which alone will bear the cost of transportation to a distant market, it must expect in the long run to submit to higher rates of rail transportation in the proportion of the diminished tonnage it will be enabled to furnish.

The same effect is produced by the building of more roads than are required to do the business of a portion of the country, under the mistaken belief that competition cheapens rates under all circumstances. The new roads, if in excess of the demand, while unprofitable themselves, will raise the cost upon the older lines, by diminishing their tonnage, and the consequent base upon which their fixed charges are to be apportioned. It is quite possible, therefore, that the recent extensive building of new roads in the West, while greatly adding to the convenience of the public, and cheapening transportation from the farm to the nearest railroad station, may yet result in an increase of freight charges, whenever the class of goods to be conveyed will bear any additional burden.

It is, perhaps, the indistinct recognition of these facts which led to the system of granting subsidies, either in lands, municipal bonds or money, under which so many new roads have recently been constructed. This system has probably now passed the period of its usefulness, having induced the building of almost all roads really needed by the country, as well as a good many besides, which will not be profitable for many years, and which the owners are now very sorry to have built. Its true theory seems to be that the subsidy should form a fund, to defray the interest upon the capital invested in the road, during the years necessary for the development of its traffic, without interfering with the growth of the country, by imposing high rates of transportation. It is greatly to be regretted that it has been perverted in some cases, either by applying the subsidies towards the construction of the road, or by dividing them among the managers, instead of setting them apart as a reserve fund to tide over the first eight or ten years of unprofitable business.

It would lead us much too far here to discuss even the approximate cost of any particular class of shipments, or the fair rate which should be charged for it. This may roughly be done, by the general method here adopted while discussing the station service, of considering the cost of handling, billing and checking the freight, as an arbitrary charge per ton, irrespective of distance carried, varying with the character of the goods; and apportioning the other expenses in proportion to the miles run by freight trains, restoring, however, to each element its true value for the particular case in hand. This can only be done by taking up in great detail the accounts of a single road, upon which the particular shipment is to occur, and the result will chiefly be valuable for that road, and not for others; for even after the cost is ascertained, upon an assumed volume of business, it becomes a matter of judgment as to how much profit shall be charged in order to secure the maximum of revenue. All the previous calculations may thus be modified by the resulting and possibly different volume of traffic, consequent upon the introduction of the element of profit; while the subject more properly belongs to a discussion upon the relations of the railroads to the public.

The object of the remarks which led to the writing of the present paper, was to show how and why the cost and charges differed upon various roads. That purpose will be accomplished, if what has been said tends to promote such investigation and discussion by others, as to lead to a better understanding of the subject, and to the further investigation of the principles which govern the cost of railroad traffic.

REPORTS OF ENGINEERS' SOCIETIES.

American Society of Civil Engineers.—Proceedings of the Society, *March 18th*, 1874.—A stated meeting was held at 8 o'clock P. M.

A paper, by John G. Clarke, C. E., on the "Approximate Value of a Reduction of Ruling or Maximum Grades," was read and briefly discussed.

The subject, "Tests of Materials used in Construction and Testing Machines," considered at the stated meeting, held January 21st, was again taken up. O. Chanute, C. E., presented a report made by Russel H. Curtis, C. E., on "Tests of Eye-Bars for Iron Bridges on the Erie Railway," which was read, and a discussion followed.

April 1st, 1874.—A regular meeting was held at 1½ o'clock P. M.

The vote upon admission to membership was canvassed, and the following declared elected: Members, John M. Brown, C. E., of Auburn, N.Y.; Abraham B. Cox, Jr., C. E., of Rochester, N. Y.; Gen. William B. Franklin, of Hartford, Conn.; William F. Merrill, C. E., of Buffalo, N. Y.; Charles R. Schott, Jr., C. E., of New York; Joseph S. Smith, C. E., of Philadelphia, Pa.; R. Willard Ware, C. E., of Port Jervis, N. Y.; and Joseph Wood, C. E., of Washington, D. C.; and Juniors, Joseph B. Davis, C. E., of Ann Arbor, Mich.; David Reeves, C. E., of Philadelphia, Pa., and Samuel Whinery, C. E., of Butterville, Ind. The resignation, on March 12th, of H. L. Koons, C. E., Associate, of Los Angelos, Cal., was announced.

A paper, by Prof. Robert H. Thurston, on the "Strength, Ductility, and Resistance of Materials of Machine Construction;" a communication from Edward Turner, C. E., referring to the "Elements of Cost of Railroad Traffic," and one from Gorham P. Low, Jr., C. E., suggesting measures for making a comparative examination of the principal pumping engines in use, were read. The latter was referred for consideration and report to a committee consisting of Messrs. Gorham P. Low, Jr., John Bogart, W. Milnor Roberts, and William E. Worthen.

The expediency of a change in location of the rooms of the Society was referred to Messrs. John Bogart, Francis Collingwood, and G. Leverich, as a committee to obtain requisite information, and report to the Board of Direction, which was empowered to act in the matter.

Of the Board of Direction.—*March 30th*, 1874.—A stated meeting was held at 2 o'clock P.M., and proposals for admission to the Society were considered.

A report from the committee appointed to prepare a detailed plan for the Sixth Annual Convention of the Society, to be held in New York, June 10th and 11th, was adopted; the Committee on Library was requested to present a scheme for the division of the books, maps, and similar property of the Society, into works of reference, which shall not be removed from its rooms, and works which may be loaned to members; and the Secretary was instructed to send a circular to members of the Society and to managers of public works generally, asking the donation of new and old reports, odd pamphlets, and similar matter, which may furnish a basis for the history and comparison of engineering operations.

IRON AND STEEL NOTES.

Steel Prize in Berlin.—It is known that steel, when quickly cooled after heating, assumes more or less hardness and brittleness; the color, texture, and density of the material being altered. As to the causes of difference between hardened and unhardened steel, there are merely conjectures on the subject. At a recent meeting of the Berlin Academy of Science, one of the secretaries, Dr. Du Bois Reymond, announced that a prize of 100 ducats (about £40) would be awarded in July, 1876, to any one who would best solve the problem, by experiment, whether the causes referred to were physical or chemical, or both. Accurate comparative analyses are required, especially of the relative quantities of carbon in the free and combined state, and also observations of the physical qualities of the materials. The memoir may be written in German, French, Latin, or English, and is to be sent to the Academy (with sealed note and motto) before the 1st March, 1876.

The Iron Produce of the World.—The Official Report of the Vienna Exhibition gives the annual "output" of iron in the producing countries as follows: England (1871) 134,664,227 cwt.; Zollverein (German bund) (1871) 33,296,042; France (1871) 23,620,000; Belgium (1871) 11,406,480; Austrian Hungary (1871) 8,492,122; Russia (1871) 7,208,141; Sweden and Norway (1871) 6,138,347; Italy (1872) 1,474,180; Spain (1866) 1,474,180; Switzerland (1872) 150,000; total for Europe, 227,793,099. North America (1872) 46,900,000; South America, 1,000,000; Japan (1871) 187,000: other countries of Asia (approximated) 800,000; Africa, 500,000; Australia, 200,000; total for the world, 276,500,000 cwt. It appears from this statement that England produces more than one-half of the whole amount, North America, about one-fifth, France about one-twelfth, and Belgium one-twenty-fourth; these four constituting the great iron-producing countries of the globe.—*American Manufacturer.*

RAILWAY NOTES.

Spliced Carriages on the Mexican Railway.—The Mexican Railway, which extends from the seaport of Vera Cruz to Puebla and Mexico, a distance of about 300 miles, has occupied several years in its construction. Political movements and changes of Government, and other disturbing influences have all done their share to retard the completion of this great enterprise. The entire system was completed and opened for public traffic in January, 1873. For some years previous to this latter date portions of this line, or from Vera Cruz to Paso del Macho, 47¼ miles, and from Puebla to Mexico, 115¾ miles, have been in operation.

As these pieces of line presented no very exceptional features in the way of curves and gradients, the passenger carriages of the ordinary English pattern were found to answer very well.

When pushing on with the construction of the remaining portion of the line, connecting the lower with the upper table-lands, it became necessary to consider some method of modifying the existing carriages to enable them to pass with safety and facility round the inevitable sharp curves which must be encountered in ascending the mountain range. The summit level of the railway on the upper table-land is some 8 400 ft. above the level of the sea, and the gradients and curves during the 60 miles before reaching that altitude are very heavy. There are more than 15 miles of line on one almost continuous gradient of 1 in 25, and also long and frequent lengths of 1 in 33, and 1 in 40.

It will be readily understood that if the characteristic features of the country necessitate such extremely steep gradients, so in like manner would curves of small radius become almost inevitable. In locating the line through the mountain range, advantage has been taken of the available spurs of the hillsides, and although heavy works have been constructed in the way of cuttings, embankments, bridges, and tunnels, it was found impossible, even with these, to obtain better curves than 325 ft., and 250 ft. radius, unless by incurring works of vast magnitude and expense. In view of these numerous curves of 325 ft. and 350 ft. radius, it was considered inexpedient to work the passenger traffic on this part of the line with carriages of the ordinary English pattern, having a rigid wheel base of 11 ft., 12 ft., or 14 ft. To have placed a four-wheeled American bogie truck at each end of so short a carriage, would have added greatly to the weight of the carriages, by employing eight wheels to carry the load, where four would be ample, and the tendency to lateral movement, inherent in the bogie system, would be much felt in a vehicle of so short a length.

It was at this time that the idea suggested itself to Mr. W. H. Mills, M. Inst. C. E., the general manager of the line, to splice the carriages together in pairs, and to make in this way one carriage about 45 or 48 ft. long, with an American four-wheel bogie truck at each end.

The carriages built by the Ashbury Carriage Company, England, offered special advantages for this splicing together. The main frames, which are of rolled wrought iron, have been spliced or fished together with strong wrought-iron joint plates 3 ft. 6 in. long, well riveted, thus making each of the main frames in one continuous piece or girder. To assist in stiffening these frames, three tension or truss rods 1¼ in. in diameter, have been placed and carefully adjusted under the carriages. The carriage bodies, which are of teak, have also been strongly bolted together at the sides and roof. A four-wheel centre-pin bogie truck built by Gilbert Bush and Co., of Troy, New York, has been placed at each end of the carriage. In addition to the Westinghouse air-brake, which is fitted up on all the carriages of the Mexican Railway, one brake placed on the top of the carriage applies the brake shoes, which are of iron, to all the eight wheels at once.

The result of this splicing of two carriages together has been a perfect success, and all those that have been thus treated, are now by far the easiest and smoothest-running carriages on the line. They pass with ease around the sharp curves above alluded to, and for some weeks had to pass daily round two provisional curves of 150 ft. radius.

The first of these spliced carriages commenced to run in January, 1871, and has now been running daily nearly three years. No repairs have been required beyond painting, varnishing, and renewals of axle box brasses. Several other carriages have since been altered in the same way.

The carriages having first and second-class accommodation are 46 ft. 3 in. long, and carry 74 passengers. They have three first-class compartments, each holding eight persons, and five second-class compartments of ten each.

The carriages combining second and third class are 44 ft. 9 in. long, and carry 90 passengers. They have nine compartments, four for second-class and five for third-class, the compartments holding ten passengers.

These spliced carriages are in daily use on the through trains between Vera Cruz and Mexico, and are found equally efficient on the comparatively level and straight road on the upper plains, where the running speed is much greater than on the more difficult parts of the line. They are very easy both for the passengers and the permanent way, and are free from shaking when running at high speed, and do not grind when passing round sharp curves.

A RUSSIAN engineer named Sakhovsky has invented an apparatus—a kind of differential gauge—of very simple construction, which is said to have been found to work admirably at the Moscow terminus of the Nijni Railway, and on several other lines. The apparatus consists of a beam about 5 ft. long, provided at one end with an articulated lever, on the shorter arm of which is a stud that presses by means of a spring against the inner face of one of the rails, and at the other with a fixed stud; the beam is drawn along the rails by a man by means of shafts, or it may be attached to a truck. As the gauge proceeds along the line the deviations from the normal width between the rails is shown by the longer arm of the lever, which moves against a dial plate. The apparatus cost only eight roubles, and its superiority over the common gauge is striking, especially as regards the rapidity and continuity of the action. The Directors of the Nijni and other lines have adopted the invention, which we believe is patented. Such a gauge run along a line every morning might prevent many an accident.

UNION PACIFIC RAILWAY.—Last year this company began the boring of six artesian wells in the arid districts, in order to obtain supplies for locomotives, which had been in part supplied by water trains. The first well is at Separation, 724 miles from Omaha, and the last one is at Rock Spring, 832 miles. Another is in progress at Red Desert. The well at Rock Springs is 1,145 ft. deep; the bore is 6 in. in diameter. In all the wells it was necessary to tube a great part of the way. At Rock Springs the water rises from the depth of 1,145 ft. 26 ft. above the surface, and discharges 571 gallons per hour, and at the surface, 960 gallons. At Point of Rocks, 25 miles east, the well is 1,000 ft. deep. The water rises only to within 17 ft. of the surface, whence it is pumped, but the supply is abundant, and the quality of the water is the best of all the wells. The next well is at Bitter Creek, 21 miles east of Point of Rocks. It is 696 ft. deep. It yields, by pumping, 2,160 gallons an hour, and at the surface it flows 1,000 gallons an hour. Next, to the east, is the well at Washakie, 33 miles distant. It is 638 ft. deep, and at 15 ft. above the surface it flows 800 gallons an hour. At Creston, 14 miles east, the well is 326 ft. deep, and an ample supply of water is obtained. At Separation the well is 1,103 ft. deep, and water comes within 10 ft. of the surface, which by pumping yields 2,000 gallons an hour.

In some of the wells the water has 280 grains of salt in solution, and the incrustation is considerable; but altogether the wells have been a success, and, it is said, the cost of running water trains since the wells have displaced them would have paid for the wells.

ENGINEERING STRUCTURES.

COLLAPSE OF A TUNNEL NEAR MERTHYR.—An accident has occurred in the tunnel between Merthyr Tydvil and Aberdare, on the Vale of Neath, Great Western Railway. This tunnel is about two miles in length. It passes through the mountain at an elevation of about 500 ft. from the bottom of the valley, and intersects many of the coal measures. Indeed, several years ago, the colliers working a neighboring colliery had got under the tunnel in the excavations, and were so close to the roadway that they could hear the trains rolling over it distinctly. The excavations of coal have proceeded, and it is supposed the cavities thus formed have seriously interfered with the bed of the tunnel. A passenger train from Swansea to Merthyr had a very narrow escape. It passed in safety; but a goods train which followed it half an hour afterwards became blocked, and it was found that the tunnel had collapsed, the locomotive half burying itself in the *débris.* Although there were continual falls, the engineers cleared for a train, and the passengers were in their places awaiting the signal, when suddenly alarming news was received that nearly a hundred yards more of the tunnel had fallen in, and traffic could not be restored for several days. Meantime the traffic had to be carried over the Taff Railway to Quaker's-yard Junction.

THE CHANNEL PASSAGE.—A new suggestion, says the *Pall Mall Gazette*, for improving the Channel passage is offered by M. Roumien. As the shallowness of the French and English shores and the constant shingle drift offer great hindrances to the formation upon the coast of harbors which will receive large steamers at any time of the tide, this engineer proposed to construct harbors two or more miles out to sea, approached by tunnels from each shore. Accommodation would thus be provided for vessels drawing such a depth of water as would insure steadiness of motion in any except stormy weather. The harbors the says) would present no engineering difficulties. They might be formed upon the same principle as the Plymouth breakwater, concrete blocks being placed by divers below the sea-level. Upon the superstructure a lighthouse would be raised which would also form a ventilating shaft to the tunnel. Access to the railway tunnel would be gained by sinking a large caisson to the necessary depth, and the excavation from it would help to form the outside slopes of the harbor. The tunnel on either side would not be of a length to require ventilation, except at the two ends, particularly as M. Roumieu proposes to dispense with engines, and the air would not therefore be deteriorated by smoke or steam. An inclination of the rails seaward would carry the train to the deep sea harbor; an endless rope, worked by a stationary engine, would draw the train back again. The passengers and their luggage would be brought to the water level by a powerful lift, and they would then embark on board large and swift steamers, which would perform the passage of, say, sixteen miles in about an hour, the transshipment being no more than is now necessary, and the liability to sickness being reduced to a minimum. Such is the compromise suggested by M. Roumieu between the proposal to tunnel all the way and not to tunnel at all.

THE TAY BRIDGE.—The report of Mr. T. Bouch, the engineer of the Tay Bridge undertaking, to the Directors of the North British Railway Company, states that the contractor for the bridge portion of the works had completed twenty spans, piers, and girders. The pier for another span was up to the full height, and ready for a set of girders. The piers of three spans were built up to within 26 ft. of their full height. Two piers were built up to 4 ft. above high-water line. Two piers were sunk to their full depth, concreted, and made ready for the columns above. Two piers were sunk about 17 ft. into the clay, and five caissons were placed in position on the bed of the river. Altogether there was a length of upwards of 3000 ft. of the bridge completed and in progress. He had been disappointed that more progress had not been made; but, besides the difficulty arising from the strata through which the caissons had to be sunk, the exceptionally severe gales in December and January last seriously interrupted the operations, and caused material damage to the staging and plant, but no damage was sustained by any part of the permanent works. As much of the work which had been done during the past six months was under water level, the progress really made was far in excess of what was apparent, and by the end of the next six months the bridge would present a very different and more satisfactory appearance.

ORDNANCE AND NAVAL.

THE NEW FIELD GUNS FOR THE GERMAN ARTILLERY.—After the trials which took place in October last, in presence of the Emperor, the introduction of the light calibre of the future guns for the German artillery has been determined upon. The heavy calibre to be used, respecting which the choice lay between two models, has also at length been definitely adopted. The manufacture of the guns is in full progress at Krupp's establishment at Essen.

We ("Cologne Gazette") are enabled to give the following reliable particulars with regard to the new field guns. The light calibre, 7.85 centimetres, is similar to that of the former light 4-pounder field gun, or that of the 8-centimetre gun, the heavy calibre, 8.8 centimetres, being on the contrary, lighter than the old six-pounder or 9-centimetre gun, which had a calibre of 9.15 centimetres. The new light field piece will be introduced into the horse batteries, while all other batteries will be armed with the heavier gun. Both descriptions are so-called case or jacket barrels (Mantelrohre), *i. e.*, the cast steel barrel is, from the breech forward, as far as the trunnions, encased in a wrought-iron jacket, which is welded round it in a red-hot state, and, after cooling, tightly encloses it. The breech is the so called Broadwell cylindro-prismatic arrangement. Both kinds of barrels have 24 grooves, and a twist of 50 times the length of the calibre. The carriage is almost the same for both guns, so that only one kind of reserve carriage need be taken, and, in case of necessity, light and heavy batteries may mutually supply each other. The cheeks are made of a single piece of rolled cast-steel plate, bent in loop-form at the trail end for the formation of the pintle hole. The cheeks consequently do not run parallel, as formerly, but converge towards the end. The axle is likewise of cast steel, and only the wheels are still of wood. The latter are about 6 in. higher than formerly, and the height of firing of the new guns is raised about as much. The traditional blue color hitherto used for painting all the wooden parts of field artillery materials, is discarded; in future the wood is to retain its natural color, and will only have a coating of linseed oil to protect it against wet.

The limber will also have wheels considerably higher; the ammunition box will be made of sheet iron, and will not be opened, as formerly, from above, but will be divided into slides, four in a row, drawn out from behind. Each ammunition box will carry, besides two case shot, 20 shells or shrapnels, probably 10 of each. Besides these, two reserve case shot will be carried in a receptacle on the carriage cheeks.

The strengthening of barrel and carriage caused by raising the weight of the charge as compared with former guns, has involved an increase in the total weight of the guns. The weights of the different parts of light and heavy field guns will, in future, be as follows:

Weight of barrel 391 and 452 kilogrammes respectively, as against 290 and 433 respectively.
Carriage, empty, 473 and 525 kilogrammes respectively, as against 453 and 520 respectively.
Barrel and carriage ready for action 890 and 1010 kilogrammes respectively, as against 772 and 101 respectively.
Limber, empty, 472 and 480 kilogrammes respectively, as against 459 and 459 respectively.
Limber, ready for action, 830 and 870 kilogrammes respectively, as against 805 and 822 respectively.
The whole gun, ready for action, 1725 and 1890 kilogrammes respectively as against, 1579 and 1837 respectively.
Draught load per horse 290 and 322 kilogrammes respectively, as against 262 and 305 respectively.

It will be seen that the increase of weight is greatest for light calibres.

The new ammunition differs also essentially from the old. The shells are double-cased, *i. e.*, two separate cases are fitted in zig-zag into each other, inclosing one another. This clever contrivance multiplies the number of pieces in bursting, and consequently increases considerably the effect of the shot.

The double-case shell of the light gun makes, at a range of 1,500 metres, on an average 60, that of the heavy gun, 90 hits. The projectile is guided in the grooves, in place of the old lead casing, by two rings of plain copper wire, pressed into corresponding furrows of the iron core, and riveted together at the ends. This arrangement, however, has not yet been definitively adopted, more extensive trials having lately taken place with hard lead rings, fastened according to a peculiar method, at present the secret of the firm of Grüson, of Buckau. But at present the copper rings seem to have the preference, partly on account of cheapness, partly because preventing loss of velocity of the projectile by friction against the grooves. The shell of the light gun weighs 6.5 kilogrammes, that of the heavy gun 1 kilogramme more, the spherical case-shot 6.8 and 7.6 kilogrammes respectively, consequently not much more than the old projectiles. The powder charge, on the contrary, is 1.25 and 1.5 kilogrammes respectively, as against 0.5 and 0.6 kilogramme, more than double the old charge. This heavy charge insures very great initial velocity and grazing of the trajectory, and thereby considerably increases accuracy of firing, especially against vertical targets. At the trials held last October, at which the known distances of the old guns were in favor of them, at a distance of 1,500 metres, the effect of the shells of the old compared with those of the new guns was in the proportion of 1 : 2.5, that of the case-shot as 1 : 3. For shorter distances, on the contrary, the shell has been found to be relatively less effective, as in that case the great velocity inherent to the projectile had driven it deep into the ground before the percussion fuze acted and caused it to explode. The construction of quicker-acting fuzes is under consideration; on the other hand, a regulation forbidding the firing of shells in future at distances under 1,200 metres might be put in force. The model of the new case-shot, only to be used for repelling sudden attacks of cavalry, has not yet been definitively chosen. Tenders have been invited for the supply of iron cores for shells and case-shot.

The new powder, very coarse-grained, and similar to English pebble powder—each grain having the size of a hazel nut—is being manufactured in private as well as in State powder mills.

At present the works at Essen have in hand only the light guns, of which Prussia has ordered 458, and Bavaria 54 pieces—the total want for the horse artillery, inclusive of reserve batteries. It is intended to supply all horse batteries with the new gun before this year's target practice commences. Two batteries of the field artillery of the Guards have already been armed with it.

In future every battery will be furnished with a telescope and stand for observing the effects of the firing, and every officer will be provided with a level of the newest construction.

THE "CITY OF PEKING."—This latest addition to the Pacific Mail fleet of thirty-five steamers had not, up to the date of launching, been measured for register, but her gross burthen will fall very little short of six thousand (6,000) tons. Her extreme length of hull is 423 ft., by 47 ft. 3 in. breadth of beam, and she is 36 ft. deep between the top of the keel and the spar deck. She has four decks, and six water-tight compartments. She has accommodations for 150 cabin passengers, and 1,500 steerage passengers, and her coal bunkers will carry 1,500 tons. The bulkheads are fitted between double frames, so as to insure the greatest tightness and resistive power in the event of it ever becoming necessary to depend on them for safety. All the deck beams are placed on every alternate frame, with "knee" plates forged on them, and are riveted to the frames and stringers. Calculation has been made and jointings and sockets prepared for beams to support the engines and boilers in too many ways to admit of detailed description. The "shell plating" of the vessel varies in thickness. No plate is less than 12 ft. long, and each plate tapers to suit the ship's sheer. Every shell plate has been tested, before being put into the ship, to several times the strain, in both simple and compound relations, it can ever be called upon to bear in actual use. All shell plates are flush jointed on the vertical section, and lap jointed on the longitudinal section; they are all riveted according to the rules of the Bureau Veritas.

All the ship's skylights are arranged to combine the maximum of utility, strength and water-tightness. The rudder is of the best hammered scrap iron, and every means that intelligence has devised and experience confirmed as useful has been employed to render this important part of the vessel absolutely secure.

The City of Peking is furnished with the most approved steam steering apparatus, as well as two other hand wheel steering apparatuses, one forward and the other aft. The steam apparatus is furnished with a friction brake to hold or stop the rudder at any point, and with a pointer to indicate exactly at what degree the rudder is at any moment.

The engines of the City of Peking are correlative with the magnitude of the vessel. They represent 5,000 horse-power, and constitute, with one exception, the largest piece of mercantile marine machinery ever constructed. They consist of two pairs of compound engines. The stroke is 54 in. There are two low-pressure cylinders of 88 in. each, and two high-pressure of 51 in. each—thus giving an aggregate cylinder-diameter of 278 in. Either engine may be detached from the other, and in case of breakage of one of them at sea, the sound one may be worked while the other is in process of repair, and will propel the vessel at two-thirds of its regular speed. The pumps for circulating the water through the surface condensers are independent of the main engines, which is a decided improvement.

This colossal machinery is to be furnished with steam from ten cylindrical boilers 13 ft. in diameter by 10 ft. 6 in. long, the shell of each boiler being 13-16 of an in. thick, and double riveted. Each boiler has three cylindrical furnaces, with 204 tubes 3¼ in. outside diameter, by 7 ft. 6 in. long. The total grate surface in these ten boilers is 520 sq. ft., and the total heating surface is 17,000 sq. ft. This is the largest heating surface ever provided for the engine of any mercantile compound marine engines, and will evolve valuable economic results in permitting slow combustion of fuel while the machinery is at full working power, and thus insuring a development not very often attained—namely, the complete consumption of all the coal put into the furnaces.

The propeller is a Hirsch screw, 20 ft. 3 in. in diameter, with 4 blades, and a mean pitch of 30 ft. In case of leak the ship's pumps are capable of throwing 10,000 gallons (250 barrels) of water per minute. There are four donkey engines with separate boilers, which may be worked in connection with or detached from the main boilers. There are three freight hatchways on deck, each furnished with a steam winch for hoisting and lowering freight. The forward winch also works the anchor, and the sails are hoisted, set, and furled by means of these winches, thus reducing the labor of the crew to a minimum.

Nothing has been left undone to render the City of Peking, in every possible respect, an absolutely perfect vessel. She enters the water as the Pride of the American Navy, and, without detracting from the worth of any foreign vessel, has no equal now afloat available for commercial purposes. She is one-fourth larger than the Celtic, the largest White Star ship. Three years ago the almost universal belief was that no such vessel could be built except on the Clyde

BOOK NOTICES.

The Moon; Considered as a Planet, a World, and a Satellite. By James Nasmyth, C. E., and James Carpenter, F. R. A. S. London: John Murray. For sale by Van Nostrand. Price, $15.

One is led to wonder upon first taking in hand this elegant quarto how enough profitable reading can be gathered together to fill so large a book, and still treat only of the moon. The preface answers all rational inquiries as to the plan of the work, and the abundance of illustrations of rare quality create at once a new interest in the subject. We quote from the preface:

"The reason for this book's appearance may be set forth in a few words. A long course of reflective scrutiny of the lunar surface with the aid of telescopes of considerable power, and a consequent familiarity with the wonderful details there presented, convinced us that there was yet something to be said about the moon, that existing works on astronomy did not contain. Much valuable labor has been bestowed upon the topography of the moon, and this subject we do not pretend to advance. Enough has also been written for the benefit of those who desire an acquaintance with the intricate movements of the moon in space; and accordingly we pass this subject without notice. But very little has been written respecting the moon's physiography or the causative phenomena of the features, broad and detailed, that the surface of our satellite presents for study. Our observations had led us to some conclusions respecting the cause of volcanic energy, and the mode of its action as manifested in the characteristic craters and other eruptive phenomena that abound upon the moon's surface. We have endeavored to explain these phenomena by reference to a few natural laws, and to connect them with the general hypothesis of planet formation which is now widely accepted by cosmologists. The principal aim of our work is to lay these proffered explanations before the students and admirers of astronomy and science in general; and we trust that what we have deduced concerning the moon may be taken as referring to a certain extent to other planets."

In explanation of the illustrations, the preface furthermore sets forth that drawings were first made of the telescopic views; these were revised and repeated, many times; no favorable opportunity for observation being lost during several years. The drawings thus made were translated into models, and these properly placed in the sunlight afforded the subjects for the remarkably vivid photographs which so abundantly adorn the volume.

The Design and Construction of Harbors: a Treatise on Maritime Engineering. By Thomas Stevenson, F. R. S. E., C. E., etc. Second Edition. Edinburgh, 1874. For sale by D. Van Nostrand. Price, $6.

It was to be expected that this standard work, first published in 1864, would reach a second edition. Mr. Stevenson has long been known and esteemed as a most reliable authority in maritime engineering. The work under notice was originally embodied in the Encyclopædia Britannica as an article on "Harbors;" and it has since been revised, both in the first and second editions of the treatise under notice; and now many aditional subjects have been introduced, while most of the chapters have been considerably extended.

The subjects treated in the several chapters are in order as follows:

I. Interior works—Exterior works—Different classes of harbors. II. Geological and other physical features. III. Generation of waves. IV. Force of the waves. V. Conditions which affect the force of waves. VI. Design of Profile, etc.. of harbors in deep water. VII. Design of Profile for tidal harbors. VIII. Design of ground plan of Harbors. IX. Docks, Tide Basins, Locks, Graving Docks, Slips, etc. X. Materials, Kinds of Masonry, Implements, etc. XI. On the efficacy of tide and fresh water in preserving the outfall of Harbors and Rivers. XII. Miscellaneous subjects relating to Harbors.

Economics of Construction in Relation to Framed Structures. By Robert H. Bow, C. E., F. R. S. E. London, 1874. For sale by D. Van Nostrand. Price, $2.

Anyone whose connection with engineering extends some twenty years back, will remember the interest with which Mr. Bow's remarkable little book or pamphlet on bracing was received. It was the first work in English which dealt with the subject in a scientific way, and there are not a few engineers, we imagine, who are of opinion that in its way, notwithstanding the many treatises since published, it has not yet been surpassed. Why Mr. Bow did not follow up his first success with similar works we cannot understand, but with the exception of an occasional Paper read before the Edinburgh Societies, we believe he has published nothing since 1851, and the "Economics of Construction" is therefore his second book. Mr. Bow adopts the same plan as before—that is, of crowding the utmost possible amount of information in a limited space. The subjects are roof and bridge trusses, and it seems hardly possible to imagine a truss of either kind which has not been considered. There are 200 varieties of roof trusses, and 132 varieties of framed bridges—numbers that, on first thoughts, would appear to be incredible. Some of these probably have never been as yet actually constructed, but they are none the less interesting as studies, and the whole series is a marvellous example of what can be done by the combination of triangular units. The method which Mr. Bow adopts for discovering the stresses, is the graphic method of which Professor Clerk Maxwell has been the improver, and the construction of the diagrams is shown for all the more important forms. Students who shirk studying theoretical books because they are not sufficiently grounded in mathematics to fully comprehend the reasoning, need have no difficulty here, where all that is required is a little patience and attention. As well as we can remember, there is no book in the language which so fully develops that most interesting process of finding stresses.

MANUEL DE TOXICOLOGIE. Par DRAGENDORFF. Paris: Librarie F. Savy. For sale by Van Nostrand. Price, $3.

This very complete manual has been translated from German into French by Prof. Ritter, who has also made numerous additions to the original work.

Besides the usual descriptions of salts credited with being poisonous and methods of testing for them, the authors have extended their work so far as to embrace deleterious articles of food and hurtful adulterations of most prepared foods.

The illustrations are not very abundant; indeed it is quite exceptional to find any in works of this class, unless micro-chemistry is added. There is but little reference to it in the present work. A beautiful spectrum chart is given, however, exhibiting spectra of hematin and hemoglobin.

MILK-ANALYSIS.—A Practical Treatise on the Examination of Milk and its Derivatives, Cream, Butter and Chese. By J. ALFRED WANKLYN, M. R. C. S. New York: D. Van Nostrand.

The plan of this new work on a new subject is best shown by the following extract from the preface, and the table of contents.

"In the course of this work, I have been fortunate enough to make some improvements in the art of milk-analysis, and, in particular, some little modifications in the taking of milk-residues, so as to tranfer such determinations (which before were tedious and uncertain) into the list of the simplest and most exact of chemical analyses. At the present time, when a new class of men has been constituted to watch over the food of the country, there is need for special manuals of this description."

CONTENTS. Chapter I—Introductory—Milk, its Nature and Chemical Composition—Description of each of its Constituents—Constancy of its Composition. Chapter II—Instruments and Methods for Testing Milk—Outline of Method of Milk-Analysis. Chapter III—Milk-Solids. Chapter IV—The Fat. Chapter V—Caseine. Chapter VI—Milk-Sugar. Chapter VII—Ash. Chapter VIII—Calculation and Statement of Results. Capter IX—The Milk Supply of the London Work-Houses. Chapter X—Cream. Chapter XI—Butter. Chapter XII—Cheese. Chapter XIII—Koumiss. Capter XIV—Condensed and Preserved Milk. Chapter XV—Poisonous Milk and Milk-Panics.

MISCELLANEOUS.

A PATENT has been obtained by M. Pirsch-Baudvin for a metallic alloy which is declared to resemble silver better than any other yet known with respect to color, specific gravity, malleability, ductility, sound, and other characteristics. The new alloy is a compound of copper, nickel, tin, zinc, cobalt, and iron. The following proportions are said to produce a very white metal, perfectly imitating silver: — Copper, 71.00 parts; nickel, 16.50 parts; cobalt, 1.75 parts; tin, 2.50 parts; iron, 1.25 parts; zinc, 7.00 parts. A small quantity of aluminum, about 1½ per cent., may be added. The manufacture is rather peculiar. The first step is to alloy the nickel with its own weight of the copper and the zinc in the proportion of six parts to ten of copper. The nickel alloy, the iron, the rest of the copper, the cobalt, in the form of black oxide, and charcoal are then placed all together in a plumbago crucible. This is then covered over with charcoal and exposed to great heat. When the whole is melted, the heat is allowed to subside, and the alloy of zinc and copper is added when the temperature is just sufficient to melt it. This done, the crucible is taken off the fire and its contents stirred with a hazel stick; the tin is then added first being wrapped in paper and then dropped into the crucible. The alloy is again stirred and finally poured into the moulds; it is now ready to be rolled and wrought just like silver. A great portion of the zinc is volatilized in the act of fusion, so that a very little remains in the alloy. The superiority of this metal is said to depend principally on the cobalt, to which is due its peculiar argentine lustre.—*Engineer.*

SOLDERING IRON AND STEEL.—As it is often necessary in manufacturing operations of different kinds to unite iron and steel by other means than welding, the following practical hints, which we translate from "Wiederholds' Gewerbeblatter," will be found worth remembering:

For large and heavy pieces of iron and steel, copper or brass is used. The surfaces to be united are first filed off, in order that they may be clean. Then they are bound together with steel, and upon the joint a thin strip of sheet copper or brass is laid, or, if necessary, fastened to it with a wire. The part to be soldered is now covered with a paste of clay, free from sand, to the thickness of one inch, the coating being applied to the width of a hand on each side of the piece. It is then laid near a fire, so that the clay may dry slowly. The part to be soldered is then held before the blast, and heated to a white heat, whereby the clay vitrifies. If iron is soldered to iron, the piece must be cooled off in water. In soldering steel to steel, however, the piece is allowed to cool slowly. The semi-vitrified clay is then knocked off, and the surface is cleaned in a proper manner. By following the hints given, it will be found that a durable and clean soldering is obtained. If brass, instead of copper, is used, it is not necessary to heat so strongly; the former recommends itself, therefore, for steel. Articles of iron and steel of medium size are best united with hard or soft brass solder. In both cases the seams are cleanly filed and spread over with the solder and borax, when the soldering seam is heated. Hard brass solder is prepared by melting in a crucible eight parts of brass, and adding one part of previously heated zinc. The crucible is then covered and exposed to a glowing heat for a few minutes, then emptied into a pail with cold water, the water being strongly agitated with a broom. Thus the metal is obtained in small grains or granules. Soft brass solder is obtained by melting together six parts of brass, one of zinc, and one of tin. The granulation is carried out as indicated above. Small articles are best soldered with hard silver solder or soft solder. The former is obtained by alloying equal parts of fine silver and soft brass. In fusing, the mass is covered with borax, and, when cold, the metal is beaten out to a thin sheet, of which a sufficiently large and previously annealed piece is placed with borax upon the seams to be united and heated. Soft silver solder differs from hard silver solder only in that the former contains one-sixteenth of tin, which is added to it during fusion. Very fine articles of iron and steel are soldered with gold, viz., either with pure gold or hard gold solder. The latter can be obtained by fusion of one part gold, two parts silver, and three copper. Fine steel wire can also be soldered with tin, but the work is not very durable. Hard and soft brass solder are used for uniting copper and brass to iron and steel, silver solder for silver, hard gold solder for gold.—*Iron Age.*

BLUE CLAY FOR BOILER WALL.—T. B. M. writes to "Leffel's Milling and Mechanical News' as follows: Our boiler wall was first laid up with lime and sand, and would crack. We took it down next the furnace twice. The second time we could not get lime and sand, and we took the blue clay from the well which we had dug, and made a rough mortar with it, full of lumps and stones. We put plenty in, and plastered the inside well; and after two months' steady hard work, firing with cobs, and cobs and coal, even the thin inside coat is on yet, and not a crack has shown itself in the brick work, although we had steam up an hour after the bricks were laid. If this piece of experience will do anybody any good, they are welcome to it, as blue clay can always be had, while lime and sand are hard to get, and expensive, especially in this region—Central Illinois.

CHINESE RIVERS.—The facilities for internal commerce afforded by its large and numerous rivers and its grand canal have for ages been the pride and glory of China. But there is said to be a black sheep in every flock, and the Hoangho or the Yellow River, the second in size within the limits of the empire, is a most capricious and troublesome stream. It has repeatedly overflowed its banks, deviated widely from its former course, and wrought immense damage in populous and fertile districts. The last time this occurred was in 1853, when it left its bed about 500 miles above the Yellow Sea, and diverging north found its way into the Gulf of Pecheelee, into which it has since flowed. This change caused it to cross the grand canal, connecting Pekin with Southern China, a large section of which is washed away, and which it rendered nearly useless. These changes are caused by the large amount of sediment deposited, raising its bed until the latter becomes higher than the surrounding plain. Then in high water the river breaks through its banks and seeks the lower level. The condition of this watercourse has lately been a matter of serious consideration before the Grand Council of China, and a report has been submitted by Li Hung Chang, Viceroy of the Province in which Pekin is situated. He recommends measures to embank the river and confine it to its present course. He says that the continuity of the canal cannot be re-established, and that rather than go through with the necessary transshipment of rice, it is advisable to permanently adopt the sea route, which, in fact, has been in use for 20 years. This will compel the abandonment of junks and the use of steamships, in order to compete with foreign vessels which are constantly plying up and down the Chinese coast, and which it is now too late to exclude. To this end Li suggests that subsidies be granted to Chinese steamship companies; also that the grain taxes be commuted into a low money tax, which would obviate the necessity of much of the transportation now carried on.

SINGLE *v.* COMPOUND ENGINES.—The Committee of the Junior Naval Professional Association offer a prize of £20 for the best essay on "The Comparative Merits of Simple and Compound Engines as applied to Ships of War." The conditions of award are as follows: 1. Competition is open to all; 2. The essays must be rendered to the Honorary Secretary, care of Messrs. Griffin & Company, Portsea, before the 1st August, 1874; 3. The essays to be strictly anonymous, but each to have a motto and to be accompanied by a sealed envelope, with the motto outside and the name of the competitor inside. It is desirable that the essay should not exceed 100 pages of the size of the Proceedings of the Association; 4. The essays will be submitted for decision to Professor Cotterill, Royal Naval College, Greenwich; Chief Inspector William Eames, R. N., Chatham; and John Penn, Esq., Greenwich; 5. The essays will become the property of the Association, to publish if desirable. Communications to be sent to the Honorary Secretary, Hubert H. Grenfell, Lieut., R. N., Portsmouth.

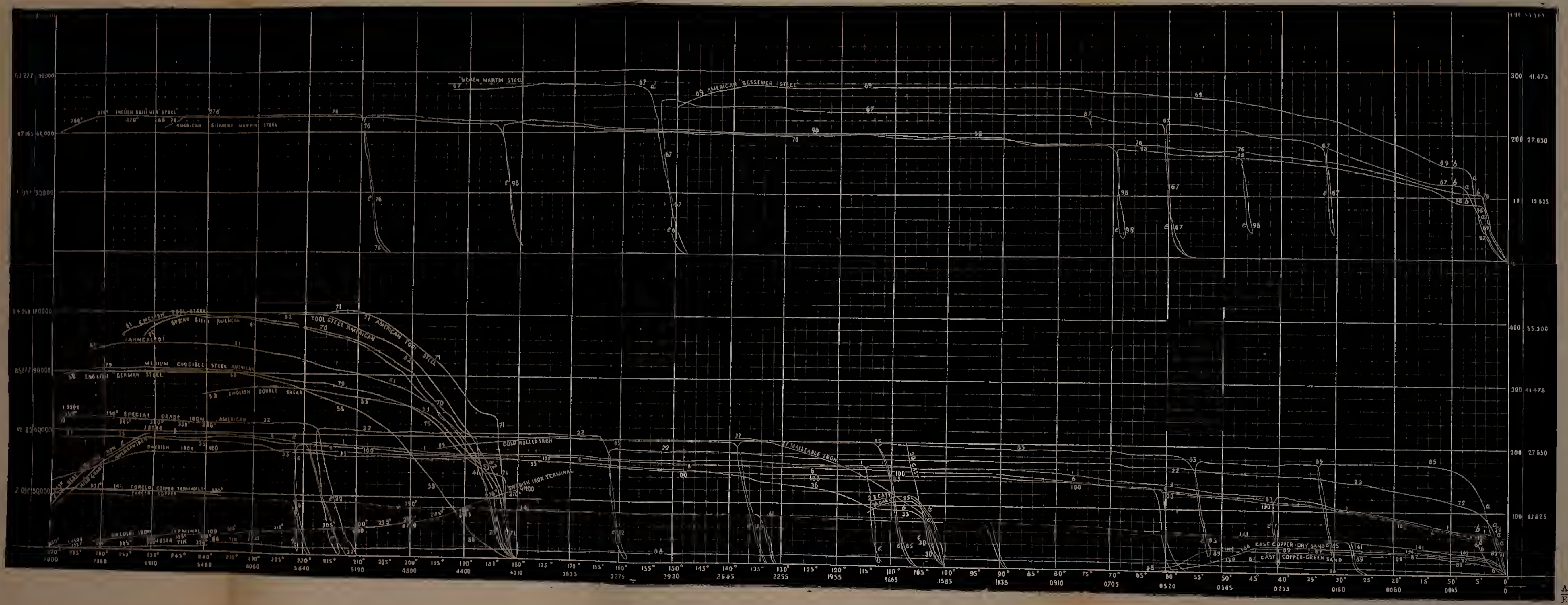
BOMBAY, BARODA, AND CENTRAL INDIA RAILWAY.—A proposal has been made for an extension of the Bombay, Baroda, and Central India Railway to Rajcote. Colonel Anderson, political agent of Kattywar, has convened a meeting of the princes and chiefs of that province upon the subject. A previous subscription made for the execution of the line produced £150,000, and at the meeting held by Colonel Anderson a further sum of £50,000 was contributed.

PLATE II

AUTOGRAPHIC STRAIN–DIAGRAMS OF METALS

PRODUCED BY THE

TESTING MACHINE OF PROFESSOR R. H. THURSTON.



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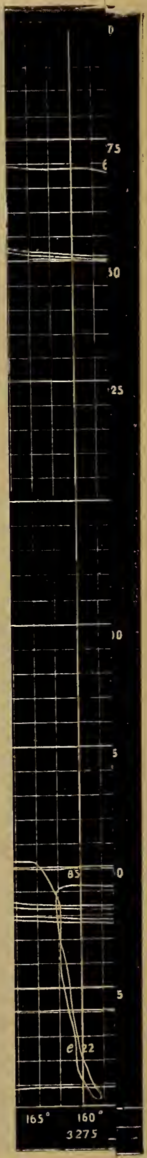

Angle of Torsion.
Elongation.

VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

No. LXVI.—JUNE, 1874.—Vol. X.

ON THE STRENGTH, ELASTICITY, DUCTILITY, AND RESILIENCE OF MATERIALS OF MACHINE CONSTRUCTION, AND ON VARIOUS HITHERTO UNOBSERVED PHENOMENA, NOTICED DURING EXPERIMENTAL RESEARCHES WITH A NEW TESTING MACHINE, FITTED WITH AN AUTOGRAPHIC REGISTRY.*

A paper by Prof. R. H. Thurston, Member of the American Society of Civil Engineers, read February 4th, 1874.

SECTION I.

1. *Introductory.*—Some months ago,† while engaged with the advanced classes of the Stevens Institute of Technology, in experimental investigations of the resistance of materials, it was found that coefficients were given, by various authorities, which neither accorded fully with each other nor with those then obtained.

The desirability of determining how far these differences were due to errors of observation, and how far to variation in the quality of the materials examined, induced the writer to design several machines for the purpose of conducting with them a more extended and exact series of experiments. The machine for measuring torsional resistance was furnished with an automatic registry, recording a diagram which is a reliable and exact representation of all circumstances attending the distortion and fracture of the specimen. No system of personal observation could probably be devised which could yield results either as reliable or as precise as such a system of autographic registry, and, as no method previously in use had given simultaneously, and at every instant during the test, the intensity of the distorting force and the magnitude of the coincident distortion, it was anticipated that the new method of investigation might be fruitful of new and, possibly, important results. This expectation, as will be seen, has been more than realized.

2. *Description of the Apparatus.*—The machine, as planned by the writer, and as built in the instrument maker's workshop at the Stevens Institute, is shown in Fig. 1. This form is that with which the investigations to be described were made. Since its construction, in 1872, however, some changes and improvements have been made in the design to adapt it to general work, and new designs have been made for special kinds of work, as for wire mills, railroad shops, and bridge building.

Two strong wrenches, C E, B D, are carried by the frames A A, A¹ A¹, and depend from axes which are both in the same line but are not connected with each other. The arm, B, of one of these wrenches carries a weight, D, at its lower end. The other arm, C, is designed to be moved by hand, in the smaller machines, and by a gear and pinion, or a worm gear in larger forms of the apparatus. The heads of the wrenches are made as shown in Fig. 2, the recess, M, being fitted to take

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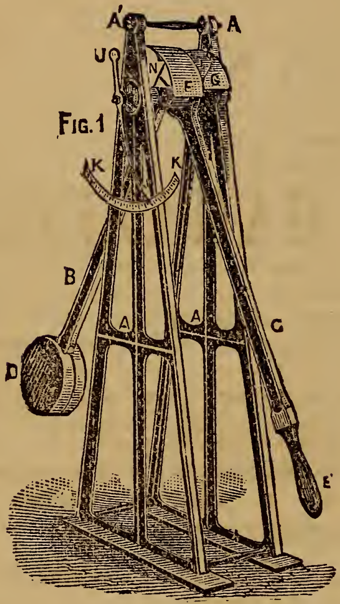
* Reprinted by arrangement with the Author and the Library Committee.

† *Vide* Journal Franklin Institute, 1873.

the head, on the end of the test pieces, which is usually given the form shown in Fig. 4.

Fig. 1



A guide curve, F, of such form that its ordinates are precisely proportional to the torsional moments exerted by the weighted arm, B D, while moving up an arc to which the corresponding abscissas of the curve are proportional, is secured to the frame A A^1. The pencil holder, J, is carried on this arm, B D, and as the latter is forced out of the vertical position, the pencil is pushed forward by the guide curve, its movement being thus made proportionate to the force which, transmitted through the test piece, produces deflection of the weighted arm. This guide line is a curve of sines. The other arm, C E, carries the cylinder, G, upon which the paper receiving the record is clamped, and the pencil, J, makes its mark on the table thus provided. This table having a motion, relatively to the pencil, which is precisely the angular relative motion of the two extremities of the tested specimen, the curve described upon the paper is always of such form that the ordinate of any point measures the amount of the distorting force at a certain instant, while its abscissa measures the distortion produced at the same instant. The maximum hand, J, is sometimes useful as a check upon the record of maximum resistance.

Fig. 2

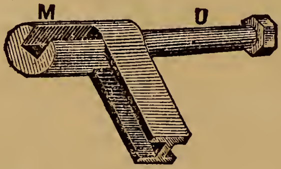


Fig. 3

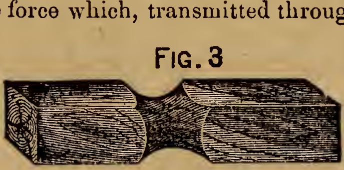


Fig. 4

The convenience of operation, the small cost,* and the portability of the machine are hardly less important to the engineer than the accuracy, and the extraordinary extent of information obtainable by it.

3. *Method of Operation.*—The test piece having been given the shape and size which are found best suited for the purposes of the experiment, and to the capacity of the machine, it is placed in the jaws of the two wrenches, each of which takes one of its squared ends, and, a force being applied to the handle, E, the strain thrown upon the specimen is transmitted through it to the weighted arm, B D, causing it to swing about its axis until the weight exerts a moment of resistance which equilibrates the applied force. As the magnitude of the distorting force changes, the position of the weight simultaneously changes, and the pencil indicates, at each instant, the value of the stress upon the test piece. As the piece yields under strains of increasing amount, also, the pencil is carried in the direction of the circumference of the cylinder on which its record is made, and to a distance which is proportional to the amount of distortion, *i. e.*, to the "total angle of torsion." As the applied force increases, the specimen yields, and finally, rupture occurring, the pencil returns to the base line, at a distance from the starting point which measures the angle through which the test piece yielded before its fracture became complete.

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* Machines of the size of that used in these experiments, but of improved design, are made at the Stevens Institute, at prices as low as \$150.

4. *Interpretation of the Diagrams.*—It has been shown that the vertical scale of the diagrams produced is a scale of torsional moments, and that the horizontal scale is one of total angles of torsion. Since the resistance to shearing, in a homogeneous material, varies with the resistance to longitudinal stress, it follows that the vertical scale is also, for such materials, a scale of direct resistance, and that, with approximately homogeneous substances, this scale is approximately accurate, where, as here, all specimens compared are of the same dimensions. Since the elasticity of the material is measured by the ratio of the distorting force to the degree of temporary distortion produced, the diagrams obtained will exhibit the elastic properties of the material, as well as measure its ductility and its resilience.

Referring to the diagrams shown in the accompanying plates, it will be noticed that the first portion of the line is a curve of small radius, convex toward the axis of abscissas, and that the line then rises at a slight inclination from the vertical, but becoming very nearly straight, until, at a point some distance above the origin, it takes a reversed curvature. The first portion of the line is probably formed by the yielding of the loosely fitted packing pieces securing the heads of the specimen, and after they have taken a bearing, by the early yielding, in some materials, of particles already overstrained. When a firm hold is obtained, the line becomes sometimes nearly straight, and the amount of distortion is seen to be approximately proportional to the distorting force, illustrating "Hooke's law," *Ut tensio sic vis.*

After a degree of distortion which is determined by the specific character of each piece, the line becomes curved, the change of form having a rate of increase which varies more rapidly than the applied force. When this change commences, it seems probable that the molecules, which, up to that point, retain generally, their original distribution, while varying their relative distances, begin to change their positions with respect to each other, moving upon each other in a manner similar, probably, to that action described by Mon. Tresca, and called the "Flow of Solids,"* and to which attention has already been called by Prof. J. Thompson.†

It is this point, at which the line commences to become concave toward the base, that is considered to mark the "limit of elasticity." It will be noticed that it is well defined in experiments upon woods, is less marked, but still well defined in the "fibrous" irons and the less homogeneous specimens of other metals, and becomes quite indeterminable with the most homogeneous materials, as with the best qualities of well worked cast-steel. This point does not indicate the first "set," since, as will be hereafter seen, a set is found to occur, either temporary or permanent, and usually partly temporary and partly permanent, with every degree of distortion, however small. It is at this "elastic limit" that the sets begin to become considerable in amount and almost wholly permanent.

The inclination of the straight portion of the line from the vertical measures the stiffness of the specimen, the quantity *Cot.* $\Theta = \frac{1}{\text{Tan. } \theta}$ being the ratio of the distorting force to the amount of distortion up to the "limit of elasticity." As it would seem from the results of experiment, as well as of deduction, that this rigidity is very closely, if not precisely, proportional to the hardness, in homogeneous substances, this quantity *Cot.* Θ may be taken, for practical purposes, as a measure of the hardness of the metals, as well as of their elastic resistance to compression.

After passing the elastic limit, the line becomes more and more nearly parallel to the base line, and then, with the woods invariably, and in some cases with the metals, begins to fall rapidly before fracture becomes evident in the specimen. Where the rising portion of the line turns and becomes nearly parallel with the axis of abscissas, the viscosity of the material is such that the outer particles "flow" upon those within, and, while themselves still offering maximum resistance, permit molecules nearer the axis to also resist with approximately maximum force. It seems probable that, with the more ductile substances, nearly all are brought up to a maximum in resistance before fracture occurs, and this circumstance will be seen hereafter to have an important influence in determining the

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* L'Ecoulement des Corps Solides. Paris, 1869, 1871.

† Cambridge and Dublin Mathematical Journal, Vol. III., 1848, pp. 252-266.

resistance to rupture. The hardest and most brittle materials break, with a snap, before any such flow becomes perceivable, and before the line of the diagram commences to deviate, in the slightest degree, from the direction taken at the beginning, and before the approach to the elastic limit is indicated. It is evident that the standard formulas for torsional, as well as for other forms of resistance, cannot be perfectly correct, since they do not exhibit this difference in the character of the resistance offered by ductile and by rigid materials.

The elasticity of the material is determined by relaxing the distorting force, at intervals, and allowing the specimen to relieve itself from distortion so far as its elasticity will permit. In such cases, the pencil will be found to have traced a line resembling, in its general form and position, in respect to the coördinates, that forming the initial portion of the diagram, but almost absolutely straight, and more nearly vertical. The degree of inclination of this line indicated the elasticity, precisely as the initial straight line was made to give a measure of the original stiffness of the test piece, the cotangent of the angle made with the vertical, Cot. $\Phi = \frac{1}{\text{Tan. } \theta}$ being the ratio of the force required to spring the piece through the range recoverable by elasticity, to the magnitude of that range. The fact, to be shown, that this value is always greater than Cot. Φ, for the same metal is evidence that more or less permanent set will always occur, and that the original stiffness of the specimen is always modified, whatever the magnitude of the applied force. The form of the line of elastic change indicates also the character of the molecular action producing it.

Finally, the form of the curve after passing the maximum, or after passing the point at which fracture commences, exhibits the method of variation of strength during the process of fracture. This portion is very difficult to obtain, with even approximate accuracy, with any but the toughest and most ductile materials. This terminal portion of the diagram would be, theoretically, a cubic parabola, the loss of resisting power varying with the progressive rupture of concentric layers, and the remaining unbroken cylindrical portion becoming smaller and smaller until resistance vanishes with the fracture of the axial line. In some cases, the curves obtained from ductile metals exhibit this parabolic line very distinctly. In all hard materials, the jar produced by the sudden rupture of surface particles is sufficient to separate those within, and the terminal line is straight and vertical.

The homogeneity of the material tested is frequently hardly less important than its strength, and it is very desirable to obtain evidence which may enable the experimenter to determine the value of tests of samples as indicative of the character of the lot from which the specimens may have been taken. If the specimens are found to be perfectly homogeneous, it may be assumed with confidence that they represent accurately the whole lot. If the samples are irregular in structure and in strength, no reliable judgment of the value of the lot can be based upon their character, and there can be no assurance that, among the pieces accepted, there may not be untrustworthy material which may possibly be placed just where it is most important to have the best. It is evident that the more homogeneous a material, the more regularly would changes in its resistance take place, and the smoother and more symmetrical would be the diagram. The depression of the line immediately after passing the elastic limit exhibits the greater or less homogeneousness of the material. The fact is illustrated in a striking manner in some of the curves presented, and we thus have—what had never, I believe, been before found—this method of determining homogeneousness.

The resilience of the specimen is measured by the area included within its curve, this being the product of the mean force exerted into the distance through which it acts in producing rupture, *i. e.*, it is proportional to the work done by the test piece in resisting fracture, and represents the value of the material for resisting shock. The area taken within the ordinate of the limit of elasticity, measures the capacity for resisting shock without serious distortion or injurious set.

The ductility of the specimen is deduced from the value of the total angle of torsion, and the measure is the elongation of a line of surface particles, originally parallel to the axis, which line assumes a helical form as the test piece yields, and finally parts at or near the point where the maximum resistance is formed. Its value is given on Plates II. and III. for each 10 deg. of arc. Since, in this case, there is no appreciable reduction of section, or change of form, in the specimen, this value of elongation is our actual measure of the maximum ductility of the material, and is an even more accurate indication than the area of fractured cross section as usually measured after rupture by tension. It is to be understood that wherever comparisons are here made, without the express statement of other conditions, specimens of the same dimensions are always represented in the diagrams.

5. *Description of Illustrated Diagrams. The Woods.**—Plates I. and II. exhibit sets of curves which illustrate the general characteristics of a large number of materials, the first showing the peculiarities noted during experiments on the woods, and the second giving an interesting comparison of the metals.

The woods experimented upon were the following, the numbers of the respective curves on Plate I. indicating the material here correspondingly marked :—

1. White pine (*Pinus Strobus*).
2. Southern pine (*Pinus Australis*), sap, wood.
3. Southern pine, heartwood.
4. Black spruce (*Abies Nigra*).
5. Ash (*Fraxinus Americanus*).
6. Black walnut (*Juglans Nigra*).
7. Red cedar (*Juniperus Virginianus*).
8. Spanish mahogany (*Swietenia Mahogani*).
9. White oak (*Quercus Alba*).
10. Hickory (*Carya Alba*).
11. Locust (*Robinia Pseudo-acacia*).
12. Chestnut (*Castanea Vesca*).

The specimens are all of the form shown in Fig. 3, three and three-fourth inches long, with a diameter of neck of seven-eighths of an inch.

It will be noticed that, in all cases, at the commencement of the line, it rises at a slight inclination from the vertical and almost perfectly straight. This confirmation of Hooke's law, within the limit of elasticity, is best shown in the detached portion *a*, *a*, *a*, of the curve obtained with locust, in which the horizontal scale is somewhat magnified. The distortion is seen to be very precisely proportional to the distorting force, until the law changes at the limit of elasticity.

It will be observed that, in the larger number of cases, the torsional resistance increases with great regularity nearly to the angle of maximum stress, where, suddenly, this rapid rate of increase ceases, and the limit of elastic resistance being passed, resistance diminishes rapidly with further increase of angular movement, until it becomes zero. In the tougher and more dense varieties, this decrease of resistance occurs less slowly, and in some cases only disappears after a large angle of torsion is recorded. In the curves of exceptionally strong and tough woods, in which there is known to exist a great excess of longitudinal over lateral cohesion, as in those of black walnut 6, 6, locust 11, 11, and especially in those of hickory 10, 10, a peculiarity is perceivable which is somewhat remarkable, and which is especially important in a connection to be hereafter referred to at length.

In these instances the resistance is proportional to the amount of torsion, until a maximum is reached; the line then falls as torsion continues, until a minimum is passed, the curve then again rising and passing another maximum before finally commencing an unintermitted descent to the axis of abscissas. Where the difference between longitudinal and lateral cohesion is exceptionally great, the second maximum may, as illustrated, for example, by the line described in recording the test of hickory, have a higher value even than the first. This interesting and previously unanticipated peculiarity was shown, by careful observation, to be due to the sudden yielding of lateral cohesion when the torsional moment reached the value indicated by the first minimum. The fibres being thus loosened from each other, this loose bundle of filaments yielded readily, until, by lateral crowding as they assumed a helical form and enwrapped each other, their slipping upon each other was gradually checked, and resistance again commenced increasing. At the second maximum, yielding again began in consequence of the breaking of fibres under the longitudinal stress measured by that component of torsional force having a direction parallel with the filaments in their new positions, the exterior surface threads parting first under this tensile stress, and rupture progressing by the yielding of layer after layer, until, the axial line being reached, resistance vanished. In this case, rupture seems never to occur by true shearing along

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* A portion of this section has appeared in an earlier number of this magazine It is here retained in order that this paper may be preserved complete, and in order that the comparison between strain-diagrams of woods and metals may be readily made.

one defined transverse plane. This feature of depression in the curve, occurring as described, is therefore the indication of a lack of symmetry in the distribution of resisting forces. It is evident that it may occur either by a difference in the value of cohesive force in the lateral and longitudinal directions or by the structural defects of a specimen in which the substance itself may be endowed with cohesion of equal intensity in all directions.

The curves shown in Plate I. exhibit well the relative values of these materials for the various purposes of the engineer.

White pine, 1, 1, 1, is shown by the considerable inclination of the line of stiffness from the vertical, to be soft and deficient in rigidity. The limit of elasticity is quickly reached, and the maximum resistance of the specimen is found at 15½ foot-pounds of moment. Rapidly losing strength after passing the limit of resistance, it is entirely broken off at an angle of 130 deg. The small area comprised by the diagram proves its deficiency of resistance, and its inability to sustain shock.

Yellow pine, 2, 2, 2, 3, 3, 3, far excels the first in all valuable properties shown by the curve. The sapwood seems, in the specimens tested, equally stiff with the heart, but it reaches the elastic limit sooner. The general form of the diagram is the same in both, and is characteristically different from that of the white pine. It evidently has great value wherever rigidity, strength, toughness, and resilience are desired in combination with lightness, the latter most important quality, together with their cheapness, aiding the qualities here shown in determining the application of these woods so extensively for general purposes. It should be noted that, since all comparisons of strength are based on measures of volume, a comparison of densities should usually be obtained to assist the judgment in making a choice from among materials of which tests have been made.

Spruce, 4, 4, 4, while possessing far less stiffness than even white pine, excels it somewhat in strength, passing its maximum at 18 foot-pounds, and submitting to a torsion of nearly 200 deg. It is proven to possess proportionally greater resilience also. It is, however, far inferior to the yellow pine in every respect.

Ash, 5, 5, 5, is more deficient in strength and toughness than is generally supposed, and rapidly loses its power of resistance after passing the maximum, which point is found at about 27½ foot-pounds. These specimens may have been of exceptionably poor quality, or, possibly, were over-seasoned.

Black walnut, 6, 6, 6, is remarkably stiff, strong, and resilient, its diagram resembling somewhat that of oak in general form and dimensions. The maximum of resistance reaches 35 foot-pounds, and the most ductile specimen was only broken off after yielding through an arc of 220 deg. Its stiffness is shown by the fact that it required a moment of 25 foot-pounds to spring it 10 deg., yellow pine requiring but 22 foot-pounds and spruce but 8 to give them the same amount of distortion.

Red cedar, 7, 7, 7, is very stiff, but is brittle and deficient in strength, breaking off at 92 deg., and having a maximum power of resistance of but 20½ foot-pounds. It is, however, one of the stiffest of the woods, its specimen requiring 20 foot-pounds of torsional moment to produce a total angle of torsion of but 5 deg.

Spanish mahogany, 8, 8, 8, is both strong and stiff, bearing a stress of 44 foot-pounds, and requiring 32 to produce a torsion of 10 deg.

White oak, 9, 9, 9, exhibits less strength than either good mahogany, locust, or hickory, but it is exceedingly tough and resilient. Passing the maximum at an angle of 15 deg., under a torsional stress of 35½ foot-pounds, it retains its power of resistance nearly unimpaired up to about 70 deg., and then slowly yields until it suddenly gives way, after passing the angle 250 deg., under a strain due to 9 foot-pounds, and breaks off completely at 253 deg. This strength, toughness, and endurance, under strains due to impact, may be attributed to its considerable lateral cohesion, and to the interlacing of its tenacious fibres, which gives this wood its "cross" grain.

Hickory, 10, 10, 10, has the highest maximum found during these experiments, the second of the pair of maxima already referred to being considerably above the maximum of locust, even. This specimen exhibits well the well-known valuable properties of the material, requiring 45 foot-pounds to twist it 10 deg., reaching a limit of elasticity at 54 foot-pounds and 13 deg., and having a maximum resisting moment of 59½ foot-pounds. When it finally yields, it does so quite rapidly, breaking off at 145 deg.

Locust, 11, 11, 11, gives an excellent

PLATE I.

Autographic Strain-Diagrams of Woods produced by the Testing Machine of Professor R. H. Thurston.

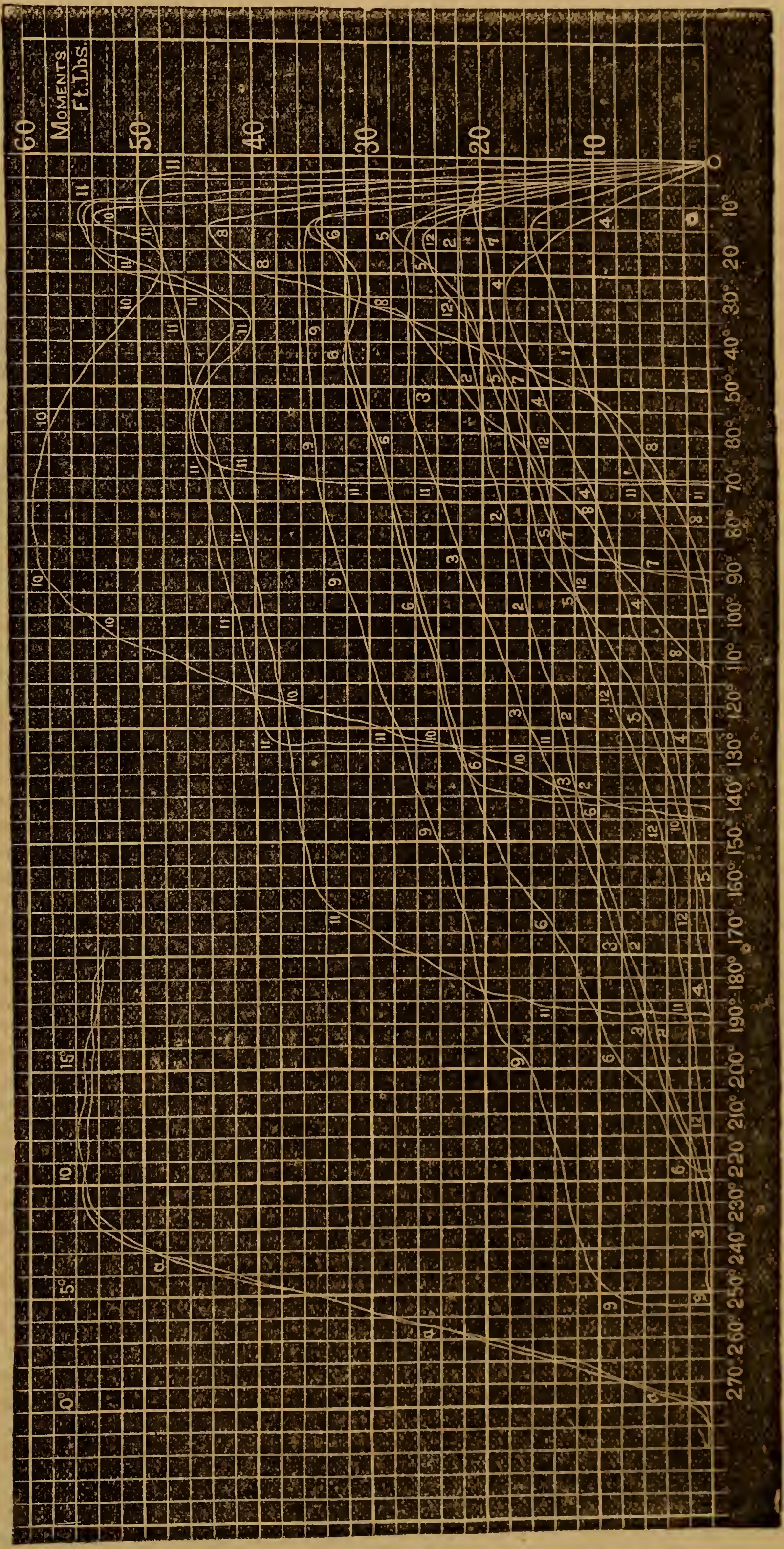

diagram. It is the stiffest of all, yielding but 10 deg. at its maximum of 55 foot-pounds, and one piece, which was unusually hard and compact, requiring 48 foot-pounds to distort it 4 deg., and reaching a maximum angle of torsion of nearly 190 deg.

It was noticed, during this series of experiments, that different specimens of the same species of wood usually exhibited very nearly equal strength and rigidity, and that marked differences were only occasionally noted in elasticity and resilience.

6. *The Metals, and the Curves produced by them.*—Plate II. exhibits a series of curves which illustrate well the general characteristics and the peculiarities of representative specimens of the principal varieties of useful metals. In some cases two specimens have been chosen for illustration, of which one presents the average quality, while the other is the best and most characteristic of its class.

The diagrams obtained by testing metals are quite different in general character from those registered in experiments on the woods, yet there are some points of resemblance which it will be instructive to notice, since these similar characteristics indicate similar properties of the two materials, and a comparison aids greatly in the interpretation of the diagrams. The woods have a structure which differs, in a distinguishing degree, both in the distribution of the substance and in the action of those molecular forces capable of resisting rupture, from that of the metals, the latter being far more homogeneous, in both respects, than the former. Wood consists of an aggregation of strong fibres, lying parallel, or approximately so, and held together often by a comparatively feeble force of lateral cohesion. The latter force being, as often happens, destroyed, the mass becomes a collection of loose threads having the general character of a rope or cord, with slight or no twist. The metals, on the other hand, are naturally homogeneous, both in structure and in the distribution and intensity of the molecular forces. Well-worked and thoroughly annealed cast-steel, as an example, is equally strong in all directions, is perfectly uniform in its structural character, and is almost absolutely homogeneous as to strain. It would be expected, therefore, that the diagrams obtained by breaking such a material would differ from those of the woods, in having a smoother and more regular form, and this is shown to be actually the case by observation of the curves of cast-steel, cast-iron, bronze, and others of the more homogeneous metals and alloys.

Some of the metals, it will be noticed, yield diagrams of less regular form. Wrought-iron, as usually made, has a somewhat fibrous structure, which is produced by particles of cinder, originally left in the mass by the imperfect work of the puddler while forming the ball of sponge in his furnace, and which, not having been removed by the squeezers or by hammering the puddle ball, are, by the subsequent process of rolling, drawn out into long lines of non-cohering matter, and produce an effect upon the mass of metal which makes its behavior, under stress, somewhat similar to that of the stronger and more thready kinds of wood. In the low steels, also, in which, in consequence of the deficiency of manganese accompanying, almost of necessity, their low proportion of carbon, this fibrous structure is produced by cells and "bubble holes" in the ingot, refusing to weld up in working, and drawing out into long microscopic, or less than microscopic, capillary openings.

In consequence of this structure we find, as we should have anticipated, a depression interrupting the regularity of their curves, immediately after passing the limit of elasticity, precisely as the same indication of the lack of homogeneousness of structure was seen in the diagrams produced by locust and hickory.

The presence of internal strain constitutes an essential peculiarity of the metals which distinguishes them from organic materials. The latter are built up by the action of molecular forces, and their particles assume naturally, and probably invariably, positions of equilibrium as to strain. The same is true of naturally formed organic substances. The metals, however, are given form by external and artificially produced forces. Their molecules are compelled to assume certain relative positions, and those positions may be those of equilibrium, or they may be such as to strain the cohesive forces to the very limit of their reach. It even frequently happens, in large masses, that these internal strains actually result in rupture of portions of the material at various points, while in other places the particles are either strongly compressed, or are on the verge of complete separation by tension. This peculiar condition must evidently be of serious importance, where the metal is brittle, as is illustrated by the behavior of cast-iron, and particularly in ordnance. Even in ductile metals it must evidently produce a reduction in the power of the material to resist external forces. This condition of internal strain may be relieved by annealing hammered and rolled metals, and by cooling castings very slowly, in order that the particles may assume, naturally, positions of equilibrium. In tough and ductile metals, internal strain may be removed by heating to a high temperature and then cooling under the action of a force approximately equal to the elastic resistance of the substance. This process, called "Thermo-tension," was first used by Professor Johnson in the course of his experiments as a member of a Committee of the Franklin Institute, in 1836,* and the effect of this action in apparently strengthening the bars so treated, was stated in the report of the committee. The fact that this effect was very different with different kinds of iron was also noted, but it does not appear that the cause of this, which they term "an anomalous" condition of the metal was discovered by them.

Metals which are very ductile may frequently be relieved of internal strain, also, by simply straining them while cold to the elastic limit, and thus dragging all their particles into extreme positions of tension, from which, when released from strain, they may all spring back into their natural and unstrained positions of equilibrium. This fact, which does not seem to have been previously discovered by investigators of this subject, will be seen to have an important bearing upon the resisting power of materials, and upon the character of all formulas in which it may be attempted to embody accurately the law of resistance of such materials to distorting or breaking strain.

Since straining the piece to the limit of elasticity brings all particles subject to this internal strain into a similar condition, as to strain, with adjacent particles, it is evident that indications of the existence of internal strain, and through such indications a knowledge of the value of the specimen, as affected by this condition, must be sought in the diagram, before the sharp change of direction which usually marks the position of the limit of elasticity is reached. As already seen, the initial portion of the diagram, when the material is free from internal strain, is a straight line up to the limit of elasticity. A careful observation of the tests of materials of various qualities, while under test, has shown that, as would, from considerations to be stated more fully hereafter, in treating of the theory of rupture, be expected, this line, with strained materials, becomes convex towards the base line, and the form of the curve, as will be shown, is parabolic. The initial portion of the diagram, therefore, determines readily whether the material tested has been subjected to internal strain, or whether it is homogeneous as to strain. This is exhibited by the direction of this part of the line as well as by its form. The existence of internal strain causes a loss of stiffness, which is shown by the deviation of this part of the line from the vertical to a degree which becomes observable by comparing its inclination with that of the line of elastic resistance, obtained by relaxing the distorting force—*i. e.*, the difference in inclination of the initial line of the diagram and the lines of elastic resistance, *e*, *e*, *e*, indicates the amount of existing internal strains.

7. *Forged Iron.*—In Plate II. the curves numbered 6, 1, 22 and 100, are the diagrams produced by three characteristic grades of wrought-iron. The first is a quality of English iron, well known in our market as a superior metal. The second is one of the finest known brands of American iron, and the third is also American make, but it does not usually come into the market in competition with well known irons, in consequence of the high price which is consequent upon the necessary employment of an unusual amount of labor, in securing its extraordinarily high character.

No. 6 at first yields rapidly under moderate force, only about 50 foot-pounds of torsional moment being required to twist it 5 deg. It then rapidly becomes more rigid, as the internal strains, so plainly indicated, are lost in this change of form, and at 6 deg. of torsion, the resistance becomes 60 foot-pounds, as measured at *a*. Here the elastic limit is reached. The next 3 deg. produce no increase of resistance. This fact shows that this iron, which was not homogeneous as to strain, is also not homogeneous in structure. We conclude that it must be badly worked and seamy, and that it may have been rolled

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* Journal Franklin Institute, 1836—7.

too cold; the former is the probable reason of its lack of homogeneous structure, the latter gave it its condition of internal strain. After the first 9 deg. of torsion, resistance steadily rises to a maximum, which is reached only when just on the point of rupture, and the piece finally commences breaking at 250 deg., and is entirely broken off at 285 deg. Its maximum elongation, whose value is proportionable to the reduction of section noted with the standard testing machines, is 0.691. The terminal portion of the line, after rupture commences, is not usually accurate as a measure of the relation of the force to the distortion. The increase of resistance between the angle 9 deg. and the angle of rupture is produced by the additional effort in resistance due to the "flow" or drawing out of particles, as already indicated, and the precise effect of which will be noticed at length in a succeeding section relating to the theory of rupture.

Applying the scale for tension, which in the case of these curves was very exactly 24,000 pounds per sq. in. for each inch measured vertically on the diagram, we find that the elastic limit was passed under a stress equivalent to a tension of 19,800 pounds per sq. in., and that the ultimate tenacity was 59,200 pounds per sq in. When nearly at the maximum the specimen was relieved from stress, the pencil descending to the base line, and the elasticity of the piece produced a certain amount of recoil. The angle intercepted between the foot of this nearly vertical line, *c*, and the origin at *o*, measures the set, which is nearly almost entirely permanent. The distance measured from the foot of the perpendicular, let fall upon the axis of abscissas, from the head of this line to the foot of the line *e*, measures the elasticity, and is inversely proportional to the modulus. A comparison of the inclination of the line made by the pencil in reascending, on the renewal of the strain with the initial line of the diagram, gives the indication of the amount of internal strain originally existing in the piece.

It will be noticed that the horizontal movement of the pencil is recommenced at I, under a higher resistance than was recorded before the elastic line was formed. In this case the piece has been left under strain for some time before the stress was relieved, and the peculiarity noted is an example of an increase of resistance under stress,* or more properly of the elevation of the elastic limit, of which more marked examples will be shown subsequently.

The exceptional stiffness and limited elastic range here shown, as compared with the other examples given, is probably a phenomenon accompanying and due to this increase of resistance under stress.

Examining No. 1 in a similar manner, we find that it is far freer from internal strain than No. 6, its initial line being much more nearly straight and rising more rapidly. It is rather less homogeneous in structure, and is forced through an arc of 6 deg., after having passed its elastic limit, before it begins to offer an increasing resistance. It is evidently a better iron, but less well worked, and, as shown by the position of the elastic limit, is somewhat harder and stiffer. No. 1 retains its higher resistance quite up to the point at which No. 6 received its incidental accession of resistance by standing under strain, and the two pieces break at, practically, the same point, No. 1 having slightly the greater ductility. When the "elastic line," *e*, is formed, just before fracture, it is seen that No. 1 has a greater elastic range and a lower modulus than No. 5. It should be observed that the line by which the pencil descends to the base line has usually no value, owing to the fact that no care is generally taken to remove the stress as gradually as it is applied. When such care is taken, the lines are usually coincident, and do not form the loop here seen. It will also be noticed that these lines often cross each other, that on the right being the important line. The elastic line formed by No. 1 at between 40 deg. and 45 deg. of torsion is seen to be very nearly parallel with that obtained near the terminal portion of the diagram, and illustrates the fact here first revealed to the eye, that the elasticity of the specimen remains practically unchanged up to the point of incipient rupture, and this fact corroborates the deductions of Wertheim† and others who came to this conclusion from less satisfactory modes of research. All experiments yet made give a similar result.

No. 22 illustrates the characteristics of a metal which probably represents one of the best qualities of wrought iron made in this or in any other country, and with which

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* *Vide* Transactions, Vol. II., page 290.

† *Vide* Annals de Chimie et de Physique.

every precaution has been taken to secure the greatest possible perfection, both in the raw material and in its manufacture. The fact that it finds a market at sixteen cents a pound proves that even such care and expense are well applied. The line of this diagram, starting from *O*, rising with hardly perceptible variation from its general direction, turns, at the elastic limit, *a*, under a moment of about 80 foot-pounds, equivalent to a tension of about 24,000 lbs. per sq. in.; and with between 2 deg. and 3 deg. of torsion only, and thence continues rising in a curve almost as smooth and regular as if it had been constructed by a skilful draughtsman. Reaching a maximum of resistance to torsion of 220 foot-pounds and an equivalent tensile resistance of over 66,000 lbs. per sq. in., at an angle of 345 deg., it retains this high resistance up to the point of rupture some 358 deg. from its starting point. The maximum elongation of its exterior fibres is 1.2, making them at rupture 2.2 times their original length. This would produce a probable breaking section in the common testing machine equal to 0.4545 of the original section.*

From the beginning to the end this specimen exhibits its superiority, in all respects, over the less carefully made irons, Nos. 1 and 6, which, it should be remembered, are themselves deservedly known as good brands. The homogeneousness of No. 22 is almost perfect, both in regard to strain and to structure, the former being indicated by the straightness of the first part of the diagram and its parallelism with the "elastic line," *e*, produced at 217½ deg., and the latter being proven by the beautiful accuracy with which the curve follows the parabolic path indicated by our theory as that which should be produced by a ductile homogeneous material. At similar angles of torsion, No. 22 offers invariably much higher resistance than either Nos. 1 or 6, and this superiority, uniting with its much greater ductility, indicates an immensely greater resilience. It is evident that for many cases, where lightness combined with capacity to carry live loads and to resist heavy shocks are the essential requisites, this iron would be by far preferable, notwithstanding the cost of its manufacture, to any of the cheaper grades. Comparing their elasticities, as shown at 210 deg., 215 deg., it is seen that No. 22 is about equally stiff and elastic with No. 1, while both have a wider elastic range and are less rigid, and hence are softer than No. 6, whose elastic line is seen at 221 deg. All of the characteristics here noted can be accurately gauged by measuring the diagrams, and constants are readily obtained for all formulas, as illustrated in a later section of this paper, in which the construction of formulas and the determination of constants will be made the subject of investigation.

No. 100 is the curve obtained from a piece of Swedish iron, marked [GF]. Its characteristics are so well marked that one familiar with the metal would hardly fail to select this curve from among those of other irons. Its softness and its homogeneous structure are its peculiarities. Its curve, at first, coincides perfectly with that of No. 6. It has, however, slightly less of the condition of internal strain, and a somewhat higher limit of elasticity. The elastic limit is found at 5½ deg. of torsion, and at a stress of 65 foot-pounds of moment, equivalent to 19,500 pounds on the sq. in., in tension. Its increase of resistance, as successive layers are brought to their maximum and begin to flow, is very nearly the same as that of the specimens Nos. 1 and 6, and the line lies between the diagrams given by these irons up to 30 deg., and then falls slightly below the latter. At 220 deg., it attains a maximum resisting power, and here the outer surface begins to rupture, after an ultimate stretch of lines formerly parallel to the axis, amounting to 0.564. Had this elongation taken place in the direction of strain, as in the usual form of testing machine, it would have produced a reduction of section to 0.64, the original area.* At this point the stress in tension equivalent to the 176 foot-pounds of torsional stress, is 52,800 pounds per sq. in. From 250 deg. the loss of resistance takes place rapidly, but the actual breaking off of the specimen did not occur until it had been given a complete revolution. This part of the diagram distinguishes the metal from all others, and shows distinctly the exceptionally tough, ductile, and homogeneous character which gives the Swedish irons their superiority in steel making. No. 22,

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* Compare Kirkaldy; Strength of Iron and Steel; pp 111, 135, for reduction in Yorkshire and Swedish bars. The elongation there given has, of course, no value as a measure of ductility.

* Compare Styffe; Strength of Iron and Steel; p. 133, Nos. 26—30.

even, although much more extensible, is harder than No. 100, and yields more suddenly when it finally gives way.

A comparison of the results here recorded with those obtained by Styffe,* will afford a good basis upon which to form an idea of the accuracy as well as the convenience of this method of deriving them. An examination of the broken test piece gives some evidence confirmatory of the record. The exterior surface of the twisted portion has an appearance intermediate between that of No. 1, Fig. 5,† and No. 22, Fig. 7, with an evident tendency to "kink." The surface of fracture is lighter and more lead-like than even No. 22, and its "fibre" is finer and texture more plastic in appearance. It is beautifully uniform in character. On one end of this specimen, where a piece had been nicked and then broken off by a sharp blow, the absence of all fibrous appearance, and the granular texture and magnificently fine, regular grain are very marked, and indicate that the material is entitled to its established position as the purest metal known in the market. The specimens themselves furnish almost as valuable information, after test, as the diagrams contain, and should always be carefully inspected with a view to securing additional or corroborative information. Fig. 5 is a sketch of specimen No. 1, and shows its somewhat granular fracture, and the seamy structure produced by a defective method of working. Fig. 6, from specimen No. 16, more nearly resembles that which gave the diagram marked 6. The metal is seen to be good, tough, and better in quality than No. 1, but it is even more seamy, and even less thoroughly worked, as is evidenced by the cracks extending around the neck, and by the irregularly distributed flaws seen on its end.

Fig. 5.

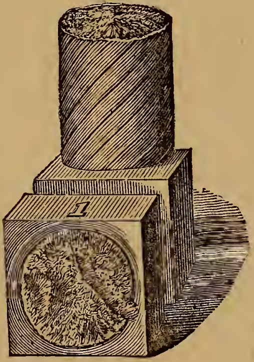

Fig. 6.

Fig. 7.

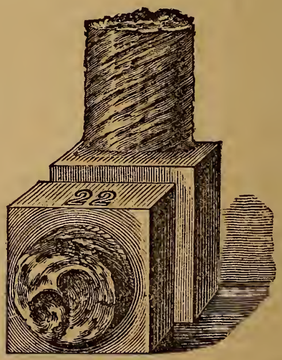

Fig. 7 exhibits the appearance of No. 22 after fracture, and shows, even more perfectly than the pencilled record, the splendid character of the material. The surface of the neck was originally smoothly turned and polished, and carefully fitted to gauge. Under test it has become curiously altered, and has assumed a rough, striated appearance, while the helical markings extend completely around it. The end has the peculiar appearance which will be seen to be characteristic of tough and ductile metals, and the uniformly bright appearance of every particle in the fractured section shows how all held together up to the instant of rupture, and that fracture finally took place by true shearing. Rupture by

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* As on last page.

† From an article in the "Scientific American," of January 17th, 1874, on "Testing the Quality of Iron, Steel and other Metals without Special Apparatus."

torsion thus brings to light every defect and reveals every excellence in the specimen. Rupture by tension rarely reveals more than the mere strength of the material.

8. *Low Steels.*—In Plate II., and above the curves just described, are a set obtained during experiments on "low steels," produced by the Bessemer and Siemens-Martin processes. In general character, the curves are seen to resemble those of the standard irons, as illustrated by Nos. 1 and 6. The irons contain usually barely a trace of carbon. These steels contain from one-half to five-eighths of one per cent. The irons are made by a process which leaves them more or less injured by the presence of impurities, from which the utmost care can seldom free them. The steels are made from metal which has been molten and cast, a process which allows a far more complete separation of slag and oxides. The low steels, however, are liable to an objectionable amount of porosity, due to the liberation of gas while the molten mass is solidifying, whenever the spiegeleisen, employed as a conveyer of carbon, is not very rich in manganese. The results of these differences in constitution and treatment are readily seen by inspecting the curves. They show a stiffness equal to No. 6, and about the same degree of internal strain. They contain a sufficient number of the capillary channels, produced by drawing down the pores while working the ingot into bar, to cause a lack of homogeneousness in structure, very similar to that produced in iron by cinder. They have a much higher elastic limit, and greater strength, and the softer grades have great ductility. In resilience, these softest steels excel all other metals, except the unusual example, No. 22, and are evidently the best materials that are now obtainable for all uses where a tough, strong, ductile metal is needed to sustain safely heavy shocks. A comparison of the diagrams of two competing metals may thus be made to indicate how far a difference in price should act as a bar to the use of the costlier one. For many purposes, a metal having double the resilience of another is worth more than double price. For general purposes, a comparison of the resilience of the metals within the elastic limit is of supreme importance. No. 6 is seen to have more resilience within this limit than No. 1, and the steels far more than either; but No. 1 would take a set of considerable amount far within the true elastic limit, as indicated at *a*. The most valuable measure is obtained by determining the area intercepted between the "elastic line" and the perpendicular let fall from its upper end; this measures the resilience of elastic resistance, which is the really important quality.

No. 98 was cut from the head of an English Bessemer rail made from unmixed Cumberland ores. It contains nearly 0.4 per cent. carbon. It is quite homogeneous, has a limit of elasticity at 88 foot-pounds of torsional, or 26,400 lbs. per sq. in. tensile stress, approaches its maximum of resistance rapidly, and, at 210 deg., the tortional moment becomes 225 foot-pounds, equivalent to 67,500 lbs. per sq. in. tensile stress. It only breaks after a torsion of 283 deg., and with an ultimate elongation of 80 per cent., equivalent to a reduction of cross section to 0.556.

No. 76 is a Siemens-Martin steel made from mixed Lake Superior and Iron Mountain ores, and contained about the same amount of carbon as the preceding. It contains rather more phosphorus, which probably gives it its somewhat greater hardness, its higher limit of elasticity and its somewhat reduced ductility. Its elastic limit is found at 104 foot-pounds of torsion, or 31,200 lbs. tensile resistance, and its ultimate strength is almost precisely that of the preceding specimen. Its elongation is 0.66 maximum. Unless more seriously affected by extreme cold than No. 98, it would be preferred for rails, and, perhaps, for most purposes.

No. 67 is a somewhat "higher" steel, made by the same process. It is less homogeneous than the two just examined, has greater strength and a higher elastic limit, but less ductility. Its resilience is very nearly the same as that of Nos. 98 and 76. The elasticity of all of these steels seems very exactly the same. The ductility of No. 67 is measured by 0.40 elongation. At *d*, is seen another illustration of elevation of the elastic limit. The piece was left twenty-four hours under maximum stress. The torsional force was then removed entirely. On renewing it, as is seen, the resistance of the specimen was found increased in a marked degree.

No. 69 is an American Bessemer steel, containing not far from 0.5 per cent. carbon. The same effect is seen here that was before noted, an increase of hardness, a higher elastic limit, and greater strength, obtained, however, by some sacrifice of both ductility and resilience. The elastic limit is approached at 130 foot-pounds of torsional moment, or 39,000 lbs. tensile, and the maximum is 280 foot-pounds of moment and 84,000 lbs. tensile resistance at 133 deg. Its maximum angle of torsion is 150 deg., its elongation 0.24.

No. 85 is a singular illustration of the effects of what is probably a peculiar modification of internal strain. It seems to have no characteristics in common with any other metal examined. Its diagram would seem to show a perfect homogeneousness as to strain and a remarkable deficiency of homogeneity in structure. It begins to exhibit the indications of an elastic limit at *a*, under a torsional moment of 110 foot-pounds, or an apparent tensile stress of 33,000 lbs. per sq. in., and then rises at once by a beautifully regular curve, to very nearly its maximum at 16 deg. and 176 foot pounds. The maximum is finally reached at 130 deg., and thence the line slowly falls until fracture takes place at 195 deg. The maximum resistance seems* to be very exactly 60,000 lbs. to the square inch. Its maximum elongation for exterior fibres is about 0.23. The resilience taken at the elastic limit is far higher than with common iron, and it is seen that this metal, in many respects, may compete with steel. Its elasticity is seen to remain constant wherever taken. This singular specimen was a piece of "cold rolled" iron. It is probably really far from homogeneous as to strain, but its artificially-produced strains are symmetrically distributed about its axis, and being rendered perfectly uniform throughout each of the concentric cylinders into which it may be conceived to be divided, the effect, so far as this test, or so far as its application as shafting, for example, is concerned, is that of perfect homogeneousness. The apparently great deficiency of homogeneousness in structure is readily explained by an examination of the pieces after fracture; they are fibrous and have a grain as thread-like as oak; their condition is precisely what is shown by the diagram, and the metal itself is as anomalous as its curve.

8. *Tool Steels.*—The "tool steels" differ chemically from the "low steels" in containing a higher percentage of carbon, and usually in being very nearly, if not absolutely, free from all injurious elements. They are made in crucibles, by melting down the blister steels, which are the crude product of the process of cementation, or sometimes, by melting a charge composed of selected iron, a small proportion of manganese bearing alloy and the proper amount of carbon. Containing a higher proportion of carbon than the preceding class of metals, it is comparatively easy to secure homogeneousness by the introduction of manganese, and by the same means, to eliminate very perfectly the evil effects of any small proportion of sulphur that may be present. Their comparatively large admixture of carbon makes them harder and reduces their ductility, and since the reduction of ductility occurs to a greater degree than the increase of strength, the effect is also to reduce their resilience. The working of these metals is more thorough than is that of the less valuable steels, or of iron. They are cast in comparatively small ingots, and are frequently drawn down under the hammer, instead of in the rolls, and are thus more completely freed from that form of irregularity in structure noticed so invariably in steels otherwise treated. The effect of increasing the proportion of carbon, is to confer upon iron the property of hardening, when heated to a high temperature and suddenly cooling, and the invaluable property of "taking a temper," *i. e.*, of assuming, under proper treatment, any desired degree of hardness. The hard steels are, however, comparatively brittle, the hardening being secured at the expense of ductility. The effect produced upon the tenacity of unhardened steel, by increasing proportions of carbon is somewhat variable, since it is influenced greatly by the presence of other elements. For good steels, unhardened, the writer has been accustomed to estimate tenacity by the following formula, which is approximately accurate, and may be often found useful:

$$T = 60{,}000 + 70{,}000\ C.$$

in which T represents the tenacity in pounds per square inch, and C is the percentage of carbon contained in the metal. This subject will be considered at greater length after a series of experiments have been made to obtain more exact determinations.

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* With an exceptional case, of which this is an example, the scale for tension is incorrect. The tensile strength is probably higher than here given.

Referring to Plate II., a set of diagrams will be found, having their origin at 180 deg., which are *fac similes* of those automatically produced during experiments upon various kinds of tool steels.

No. 58 is an English metal, known in the market as "German crucible steel." It is remarkable as having a condition of internal strain which has distorted its diagram to such an extent as to completely hide the usual indication of the elastic limit. A careful inspection shows what may be taken for this point at about 14½ deg. of torsion, when the twisting moment was about 120 foot-pounds, and the tensile resistance 36,000 pounds per sq. in. The metal is homogeneous in structure, has an ultimate resistance of 302 foot-pounds of moment, or 90,600 pounds per sq in. tensile resistance. Its resilience is evidently inferior to that of the softer metals, and also less than the next higher and better grades. This metal contains about 0.60 to 0.65 per cent. carbon. Its elongation amounts to 0.045.

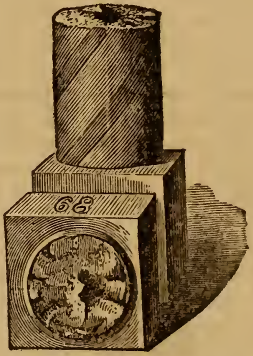
No. 53 is an English "double shear steel," of evidently very excellent structure, but less strong and less resilient than the preceding. Its exterior fibres are drawn out 3 per cent.

Nos. 41 and 61 are two specimens of one of the best English tool steels in our market. The first was tested as cut from the bar, but the second was carefully annealed before the experiment. In this instance, annealing has caused a slight loss of resilience as well as a decided loss of strength. In No. 41, the limit of elasticity can hardly be detected, but seems to be at about the same point as in No. 61, at near 130 foot-pounds moment and 39,000 pounds tension. The ultimate strength is nearly 119,000 pounds per sq. in. The proportion of carbon is very closely 1 per cent. Its section would reduce by tension, 0.05.

No. 70 is an American "spring steel," rather hard, but, as shown by its considerable resilience, of excellent quality, resembling remarkably the tool steel No. 41. It differs from the latter, apparently by its much higher elastic limit. It is possible that this may have been caused by more rapidly cooling after leaving the rolls in which it was last worked. It is evident that, for exact comparison, all specimens should be either equally well annealed or should be tempered in a precisely similar manner, and to the same degree

Nos. 71 and 82 are American tool steels, containing about 1.15 of carbon. The former is notable as having an elastic limit at 69,000 pounds, and a probable deficiency of manganese, producing the usual indication of heterogeneous structure. Both of these steels lack resilience, and are less well adapted for tools like cold chisels, rock drills, and others which are subjected to blows, than for machine tools. They have a maximum elongation, respectively, of but 0.013 and 0.03.

FIG. 8.



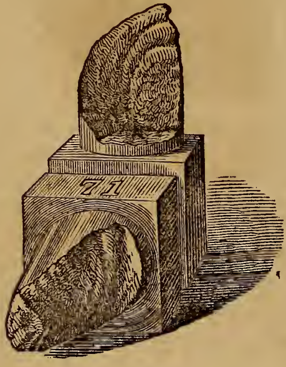
Interesting and instructive as the study of these curves may be made, the information obtained from them is supplemented, in a most valuable manner, by that obtained by the inspection of the fractured specimens, upon which the peculiar action of a torsional strain has produced an effect in revealing the structure and quality of the metal that could be obtained in no other way.

Fig. 8 represents the appearance of No. 68, and Fig. 9 that of No. 58, while the peculiarities of the finest tool steels are seen in No. 71, as shown in Fig. 10. The

FIG. 9.

smooth exterior of No. 68, which is a companion specimen to that giving diagram 69, and its bright and characteristic fracture, resembling that of No. 22 somewhat, together indicate its nature perfectly, the first feature proving its strength and uniformity of structure, and the second showing, even to the inexperienced eye, its toughness. This is a representative specimen of low steels. No. 58 is seen to have retained even more than No. 68, its original smoothly polished surface. Its fracture is less waxy, and much more irregular and sharply angular. The crack running down the side of the neck shows its relationship to the shear steels which much oftener exhibit this effect of strain, in consequence of their lamellar character. No. 58 is evidently intermediate in its character between the soft steels, like No. 68, and the tool steels which are represented by No. 71, Fig. 10. In this test piece, the fracture is ragged and splintery, and the separated surfaces have a beautifully fine even grain, which proves the excellence of the material. The surface which was turned and polished in bringing the metal to size remains as perfect as before the specimen was broken. By an inspection of the broken test pieces in this manner, the grade of the steel, and such properties also as are not revealed by an examination of the diagram of strain, are very exactly ascertained by a novice, and to the practical eye, the slightest possible variations of character are readily distinguishable.

Fig. 10.



9. *Cast-iron.*—The diagrams of strain having their commencement at 100 deg., have been obtained from cast-iron and from malleableizéd cast-iron.

Nos. 23 and 24 are those given by a good dark grey foundry iron from Pennsylvania. No. 25 represents the curve of light grey scrap, and No. 30 is from a very fine white Lake Superior charcoal iron. The latter is seen to be exceedingly hard and rigid, the resistance of the piece rising very precisely in proportion to the angle of torsion until it snaps at last under a moment of over 200 foot-pounds, equivalent to a tension of 60,000 lbs. per sq. in., and with a maximum elongation of one-tenth of one per cent. This is a most extraordinary resistance, but it is evident that, notwithstanding its immense strength, this material would be valueless for ordinary purposes in consequence of its excessive brittleness. When the torsional effort had reached about one-half its maximum amount the piece was released. The pencil retreated along a nearly vertical line *e*, which it again traversed as the strain was gradually renewed. Here as in many other cases, where a similar experiment was made, evidence is given of the truth of the statement originally made by Hodgkinson,[*] that every load produces a set. As will be shown, subsequently, however, it is not true in perfectly homogeneons bodies free from strain, and within their elastic limit. The light grey iron has a limit of elasticity at near one half the maximum reached by the white iron, without any sign of reaching the limit of its elasticity. The grey has more ductility than the white iron, but has only about two-thirds the resilience of the latter. The dark grey irons are evidently better than either of the lighter grades, except in power of carrying an absolutely static load. The actual stretch of the outer surface particles is very nearly the same in all three. They are excellent specimens of their class, and considerably better than ordinary irons.

No. 37 is a "malleableized cast-iron," made from the extraordinary metal illustrated in No. 30. The process of malleableizing consists in decarbonization by heating the casting made from good white iron, in contact with iron oxide or other decarbonizing material. Without removing any other constituent than the carbon, it produces a crude steel or an impure wrought-iron. When performed in the usual manner, melting the cast-iron in a cupola in contact with the fuel, and with some flux,

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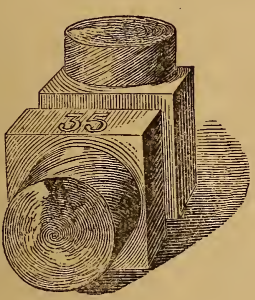
[*] Reports of British Association; also Civil Engineer and Architect's Journal.

and then carrying the process of malleableizing to the usual extent, a metal is obtained such as is illustrated by the diagram marked 37. It retains the strength of the cast-iron, and acquires some ductility.

No. 30 yielded 7 deg. before fracture, while No. 37, vastly more ductile and resilient, only broke after a torsion of 39 deg., and a maximum elongation of 2 per cent. Taking the precaution to melt the iron in an "air furnace"—a form of "reverberatory"—and conducting the process of malleableizing more carefully, a still more valuable material was obtained.

Fig. 11.



No. 35 represents this iron. Its resemblance to wrought-iron, both in appearance of fracture and in its strength and ductility, are greatly increased. It has a high limit of elasticity—over 20,000 lbs. per sq. in.—and such ductility that it only breaks after a torsion of nearly 168 deg., and an elongation of "fibre" of 0.35. It is not very homogeneous, but it is as strong, and almost as tough as a good wrought-iron. This material has especial value for many purposes, because of the facility with which awkwardly shaped pieces can be made of it. In many cases, it will prove as good as wrought-iron and far cheaper.

Fig. 12.

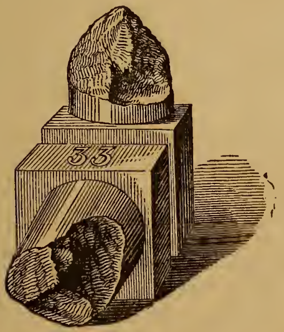
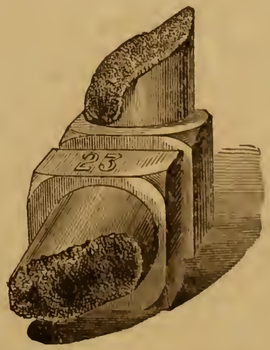


Fig. 11 shows the appearance of this last specimen. Its resemblance to wrought iron is very noticeable. The lines running like the thread of a screw around the exterior of the neck, and the smooth even fracture in a plane precisely perpendicular to the axis, are the instructive features. Fig. 12, representing No. 33, is a specimen similar in character to No. 37. The comparative lack of ductility, its less regular structure, and its less perfect transformation are perfectly exhibited. Fig. 13 is an excellent cut of the white iron as cast and without malleableizing. Its surface where fractured, has the general appearance of broken tool steel. The color and texture of the metal are distinctive, however. It has none of the "steely grain." Fig. 14 represents the dark grey iron. Its color, its granular structure and coarse grain are markedly characteristic, and no one can fail to per-

Fig. 13.

Fig. 14.



ceive, in the specimen, the generel character which is exactly given by the autographic diagrams of the testing machine.

10. *Other Metals.*—The diagrams numbered 87, 88 and 89, are those of copper, tin and zinc. These specimens are all of cast metal, carefully selected under the direction of the writer and moulded and cast at the Stevens Institute of Technology. They exhibit neatly the wonderful superiority which the various kinds of iron and steel possess over the other useful metals. These metals all take a set under very small strains, pass their limits of elasticity at some indeterminable, but evidently low point, and possess very slight tenacity.

Zinc, No. 89, by the regularity of its curve shows a very uniform structure. It increases very gradually in resistance to torsion, until it reaches the angle 50 deg., at which point it has a moment of torsional resistance of 36 foot-pounds, and a maximum tenacity of about 10,800 lbs. per sq. in. It loses its power of resistance, after rupture commences, as regularly, but not as slowly, as it acquired it, and rupture becomes complete at 63 deg. Its resistance is exceedingly small, and it is evidently unfit to bear either static or dynamic force. Its stretching power has a maximum of 0.04.

Tin, No. 88, is equally remarkable for its exceedingly feeble resistance and its great ductility. The specimen was excellent, both in quality of metal and in closeness of structure, as was indicated by the clearness of the "tin cry" heard while undergoing the test, and by the fine, smooth, clean fracture. The character of the curve is similar to that of zinc, but has far greater extent. Its elastic limit is quite indeterminable. The outline of the diagram indicates very perfect homogeneousness. The maximum resistance to torsion is found at 240 deg., and under a stress of 19 foot-pounds. Its tenacity deduced from the diagram is, at most, but 5.700 lbs. per sq. in. Rupture occurs very gradually, and the piece separated entirely at 355 deg. Notwithstanding its great ductility, its low tenacity produces a low resilience, although in this quality it excels zinc, which latter metal had nearly double its strength. Its elongation by tension would have reduced its section to 0.6 of the original cross area, if that reduction were proportional to the ductility shown by the diagram.

Copper, No. 87, cast in green sand, like the zinc and tin just described, was found, on examination of the fracture, to differ from them in being exceedingly porous. The effect of this fault has been to weaken it seriously. Its curve closely resembles that of zinc, but is abruptly terminated by the piece suddenly breaking off at 46 deg. It reaches a maximum sooner than zinc, at 29 deg., and its greatest resistance to torsion is 36 foot-pounds, or to tension 10,800 lbs. per sq. in., precisely the same as zinc. Its ductility has a value of one and a half per cent. Its resilience is somewhat less than that of zinc. Its limit of elasticity is difficult to determine, but has been taken at $1\frac{1}{2}$ deg. where the moment of resistance is 13 foot-pounds, equivalent very nearly to 3,900 lbs. tenacity per sq. in.

No. 134 is the curve of cast copper, precisely similar to No. 87, but cast in a dry sand mould. The marked difference between these specimens is probably due, not only to the difference in degree of porosity which arises from the presence of vapor, which permeates the casting in one case, filling it with bubble holes, and which is almost unobservable in the last, but the slower cooling of the dry sand casting also probably produces its effect in strengthening the metal. This last specimen has a limit of elasticity at not far from $13\frac{3}{4}$ deg., and under a torsional stress equivalent to a tension of 5,400 lbs. per sq. in. The maximum values of these quantities are found at 21 deg., and are 42 foot-pounds, and 12,600 lbs. per sq. in. respectively. The resilience of the specimen is much greater than that of the preceding, and its maximum elongation is .026. Altogether, this is far better than the preceding, and it would seem that copper, and probably all its alloys, should, when possible, be cast in dry sand, to secure density and strength.

No. 141 is a piece of forged copper, hammered into a one-inch square bar, from a piece originally $3\frac{1}{2}$ in. wide and $\frac{3}{4}$ in. thick. The most striking property noticed is its immense ductility, far exceeding that of any other piece of metal yet tested, and, in amount, many times as great as the cast metal. Its limit of elasticity is reached very quickly, although it is impossible to say precisely where it occurs. Comparing its "elastic line" with the initial portion of the curve, it is seen that the slightest force produces a set which is proportionally large as compared with the sets of other metals.

The curve rises very regularly and gradually to a maximum, which is only attained, however, after a total angle of tension of 450 deg., and which measures 96 foot-pounds moment, or 28,800 lbs. per sq. in. Rupture is finally obtained after a torsion of 543 deg. The maximum elongation is 210 per cent., the most elongated lines of particles being finally left of 3.100 times their original length. Had this change of form occurred by reduction of section, the fractured area would have been but .323 the area of original section. The resilience of this piece of metal is evidently insignificant within the limit of which it would be seriously distorted by a blow, but is quite large in amount where resistance extends to the point of rupture. This is perfectly consonant with that knowledge of the material which every mechanic derives from experience with it. Here, however, we have a complete account of its properties, written out by the material itself with definite and accurate measures.

11. *General Conclusions.*—These plates, exhibiting the diagrams, which are the autographs of all the useful metals, illustrate sufficiently well the remarkable fulness and accuracy with which their properties may be graphically represented, and the convenience with which they may be studied, with the aid of so simple a recording machine. A comparison of results deduced as shown, with those obtained, so far as they can be obtained at all, the usual method of simply pulling the specimens asunder, and trusting to, sometimes, unskilful hands and an untrained observer, for the adjustment of weights and the registry of results, will indicate the close approximation of this method in even ascertaining the behavior of the metal in tension. On examining the beautifully-plotted curves given by Knut Styffe, as representing the results of the experiments made by him and by his colleagues, with a tensile machine, no one can fail to be struck with the similarity of those diagrams to the curves here produced automatically, and it will be readily believed that not only must there be very perfect correspondence of results where the two methods are carefully compared, but, also, that any theory of rupture must be defective which does not apply to both cases. The equations of the curves here given and those of the curves obtained by Styffe must have forms as similar as the curves themselves.

The constant ratio here assumed between the torsional resistance and the tensile strength of the metals, and of homogeneous materials generally, is based upon a comparison of the results here given with those obtained from the irons by tensile test, by the writer, and is confirmed by a compilation of results given by other experiments on the same brands.

12. *Testing within the Limit of Elasticity.*—In determining the value of materials of construction, it is usually more necessary to determine the position of the limit of elasticity and the behavior of the metal within that limit, than to ascertain ultimate strength or, except perhaps for machinery, even the resilience. It is becoming well recognized by engineers who are known to stand highest in the profession, that it should be possible to test every piece of material which goes into an important structure and to then use it with confidence that it has been absolutely proven to be capable of carrying its load with a sufficient and known margin of safety. It has quite recently become a common practice to test rods to a limit of strain determined by specification, and to compel their rejection when found to take a considerable permanent set under that strain. The method here described allows of this practice with perfect safety. The limit of elasticity occurs within the first two or three degrees, and, as seen, the specimen may be twisted a hundred, or even sometimes two hundred times as far without even reaching its maximum of resistance, and often far more than this before actual fracture commences. It is perfectly safe, therefore, to test, for example, a bridge rod up to the elastic limit, and then to place the rod in the structure, with a certainty that its capacity for bearing strain without injury has been determined, and that formerly existing internal strain has been relieved. The autographic record of the test would be filed away, and could, at any time, be produced in court and submitted as evidence—like the "indicator card" of a steam engine—should any question arise as to the liability of the builder for any subsequent accident, or as to the good faith displayed in fulfilling the terms of his contract. A special machine has been designed for this case.

13. The above will be sufficient to show the use and the value of this method. In the course of experiment upon a large number of specimens of all kinds of useful

metals and of alloys, a number of interesting and instructive researches have been pursued, and some unexpected discoveries have been made. Before taking up the theory of rupture, the construction of equations, and the determination of their constants, a section will be devoted to an account of these investigations.

ROAD CONSTRUCTION IN THE HIMALAYAS.*

By Maj. JAMES BROWN.

From "Engineering."

The object of this paper was to put on record precautions found necessary whilst making roads among the Himalayas, at elevations reaching up to 24,000 ft.; where the annual rainfall in some districts amounted to 220 in., of which 170 in. fell in the two and a half months of the rainy season, and 5½ in. in one hour. Mountain roads could be divided into two classes: those which crossed the main or higher ranges, and those which crossed the lower or subsidiary ranges. The latter class generally presented the most serious engineering difficulties, owing to the greater quantity of water to be encountered. In the higher ranges, the soil, being mainly composed of hard rock, did not allow every little streamlet to cut for itself a deep and ever-increasing chasm, as in the comparatively soft soil of the lower ranges, and this circumstance rendered the bridging an easier matter. At elevations exceeding 8,000 ft. attention must be paid to the action of the snow in winter. The best approach, in an engineering point of view, to the station of Dalhousie was through a ravine, so sheltered from the sun that the snowdrifts remained unmelted for weeks, and barred the way; and it had been found necessary, in consequence, to take the new cart-road through otherwise very unfavorable ground. At Roksur, in Lahoul, a road well traced, but laid out in the height of summer, was impassable for the three spring months from incessant avalanches; one of which, half a mile in length and exceeding 100 ft. thick, carried off a stone bridge of 40 ft. span, and remained unmelted for more than six months.

In marking out the formation level, cuttings exceeding 10 ft. or 15 ft. in depth should, as much as possible, be avoided. In the stony soil of a hilly country no reliable information was to be got by boring, and rock of the toughest and hardest description sometimes cropped up where least expected. In the Himalayas, the northern slopes were thickly wooded, where the southern slopes were often quite bare. The former should be selected, notwithstanding the increased labor of tracing through the brushwood, as the road would be more durable. The trees broke the force of the rain, and the mould beneath passed it off gently over the road, which, on the bare hillside, would be cut away by the unchecked rush of water.

The general adoption of zig-zags was not to be recommended; but much had been said against them which was open to modification. They entailed incessant repairs, if used in a wrong place—where the side-slope was steep, the soil rotten, and the drainage such as to cross the road several times. But where these conditions did not prevail, the repairs were little, if at all, greater than in the same length of straight tracing. Again, where the reaches were short, and the turning-places cramped, zig-zags should not be tolerated; but where each reach was not less than 600 or 700 yards in length, and where a semicircular turn of not less than 50 ft. radius could be obtained, the inconvenience was small and the danger a minimum. Generally 5.55 in 100 was the steepest admissible gradient for an unmetalled mountain cart-road in India. No earthwork became permanent under two rainy seasons. Landslips occurred with every shower and every hard frost. On the Dalhousie cart-road, the mere cutting out of the hillside to 14 ft. in width determined a landslip upwards of 800 ft. back from the edge of the road, and parallel to it for about 700 ft.

There were three different methods of making a road along the face of vertical cliffs. The most expeditious was to form a gallery, carrying the road on cantilevers of iron or timber. This plan, however, was only suited for mule or bullock roads, and was inapplicable for cart roads. It had

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* Read before the Institution of Civil Engineers.

therefore been replaced by half tunnels blasted out of the rock. From the nearest possible standing point a gangway of lashed scaffolding poles was run out horizontally along the face of the cliff, the near end being held down by two leaded jumpers, or by lewises let into the rock. A workman from the further end of the scaffold, drove into the rock a jumper hole, slanting about 45 deg., which, when sufficiently deep, received an iron bar run with lead. To this support scaffolding was lashed, to act as a new starting point from which to advance another step. When the scaffolding so supported had extended along the whole length of the cliff, arrangements could be made for fixing the permanent cradles and cross beams to carry the gallery. On the Hindustan and Thibet road the galleries were 7½ ft. wide, the supporting cradles being from 12 ft. to 15 ft. apart. The other modes of forming a road along the cliffs were either by blasting in the usual manner, or by the use of mining galleries and heavy charges of powder. Where kunkur rock was met with, special cartridges were employed for blasting. This substance resembled petrified sponge, which, whilst allowing the powder to blow out through its pores, was so hard and tough as to defy the best steeled picks and jumpers.

On one section of the Hindustan and Thibet road, adjoining the glaciers, and where wood was abundant, blasting was abandoned for more than a year in favor of wood furnaces, while the fuel lasted. The rock, when intensely heated, and then quickly deluged with snow water, cracked and broke up, at a great saving of time and labor.

The ordinary daily task of native quarrymen in boring was about 60 in. in sandstone or conglomerate, 45 in. in limestone, and from 30 in. to 32 in. in granite. In attacking a cliff with large mines, a line of scaffolding was first erected along the face, and tunnels were driven into the rock, chambers being formed at the ends of return galleries to the right and left. The charges were placed at a horizontal distance from the cliff face of 2 ft. more than the proposed width of the road, and generally blew out the rock on both sides to a distance equal to the line of least resistance. The galleries, which were 3 ft. high by 2 ft. 6 in. wide, could, in conglomerate, be driven at an average rate of 1 in. an hour, and at a cost of about 2s. per lineal foot. The rate of progress was three times and five times less in limestone or granite than in sandstone rock or conglomerate, which rendered mining a tedious operation. The galleries for the most part were chiselled with cold steel and not blasted. The most effectual mode of tamping mines in impracticable localities was by sandbags of date or palm-tree matting, containing about ½ cubic ft. of damp clay. With these and a few half-bags and quarter-bags, the tamping was built up by native masons like an ordinary wall. Cushions of sand greatly increased the effect of the explosion. This systematic method of tamping could be done at the rate of 12 lineal ft. an hour, or three times the rate of tamping with earth, in the usual manner.

Dry masonry retaining walls were largely employed on most Himalayan roads, many of them being of great dimensions and of some constructive difficulty. Sandstone, notwithstanding its clean splitting and good bedding, was by no means so suitable a material for retaining walls as granite or limestone boulders, being liable to disintegrate under tropical rains in damp situations, as in foundations below the level of the ground. Retaining walls of what seemed most compact sandstone had suddenly collapsed, the underground courses having dissolved into sand. Where expensive masonry in mortar was used, great economy resulted from the best possible shape and dimensions being given to retaining walls; but where cheap dry masonry was employed, earth should never be used for the backing, but the space should be filled with boulders or stone chips.

The mere excavation of a wide road along a hillside at once altered the whole system of natural drainage. It was useless to commence any drainage works until the annual rains had marked out the line of discharge across the great catchwater formed by the road. On some parts of the Lahore and Peshawur road the main drains were 25 ft. wide by 5 ft. deep. On the Kangra road they averaged 10 ft. wide by 3 ft. deep. The smallest secondary drains should be 2 ft. by 1 ft. 3 in.; no cross drain, if provided with a movable slab top, being less than 2 ft. by 2½ ft., or, if permanently covered in, less than 2 ft. 3 in. by 2 ft. 9 in. To insure proper scouring, and an easy change of direction for the water, the cross drains had a slope of 1 in 12, and were built at an angle of 135 deg. with the side drain, their ends being properly secured by boulder pitching. The main drainage was carried across the road through culverts, but more especially through large outlets in dry masonry retaining walls, covered in by stone slabs of from 2½ ft. to 3 ft. span. For larger spans, up to 10 ft., and where slate was procurable, dry rubble arches were built of picked stones neatly radiated and wedged up. Where building stone was scarce, concrete arches on dry masonry abutments were largely employed, the whole mass forming a monolith, rammed up in 4 in. horizontal layers. The Durroon Bridge, on the Kangra road, was 48 ft. span in the clear by 20 ft. wide. The arch was entirely composed of rammed mortar, consisting of one part of boulder lime, one part of pounded brick, and one part of sand, no broken stone whatever being used.

The shape generally given to the metalled road surface on a mountain side was a slope of 1 in 18 from the outside to the inside. It had been objected to this slope that it converted the road into a drain, which was cut away and became impassable in heavy down-pours; and on some of the Madras hill roads the slope was from the inside to the outside. Both systems had their respective advantages; but, on the whole, the inside slope was preferable when the cross drains were sufficiently large and numerous, and the side drains rocky or properly protected by boulder paving. The usual practice was to adopt the outside slope until the drains were built and the side slopes had taken their bearings, when, as a permanent arrangement, the road was finished and metalled with an inside slope. The metalling consisted of a 9 in. layer of broken granite, kunkur rock, or coarse slate shingle, and did not materially differ from an ordinary macadamized surface. The usual width of a mountain cart road varied from 18 ft. in open ground to 12 ft. along cliffs, or in difficult places; the maximum gradients varying 1 in 18 to 1 in 25.

THE ADMIRALTY EXPERIMENTS ON SCREW PROPULSION.

From "The Engineer."

At the Norwich meeting of the British Association in 1868, the attention of the Association was drawn to the deficiency of existing knowledge on the stability, propulsion, and sea-going qualities of ships, and to the need of further experiments as a basis for the extension of theoretical investigation. A committee was appointed for the purpose of reporting on the state of knowledge on these subjects, and it was ultimately resolved by the committee that the Admiralty should be asked to carry out experiments with full-sized vessels upon some suitable water. Mr. Froude, F. R. S., who was a member of the committee, was, however, of opinion that the experiments should—at all events, at first—be carried out with models constructed on some substantial or rational scale. He contended that unless the reliability of small-scale experiments were emphatically disproved, it would be useless to spend vast sums of money upon full-sized trials, which, after all, might be misdirected, unless the ground were thoroughly cleared beforehand by an exhaustive investigation on a small scale. The final result of the application to the Admiralty was that the proposals of the committee for the full-size experiments could not be assented to, but that certain experiments with models, to be conducted by Mr. Froude, would be sanctioned, and the results of these experiments when complete would be communicated to the British Association, the Institution of Naval Architects, and other professional bodies.

We reprint, on another page, an interesting paper, descriptive of an extremely ingenious method of preparing models of ships to be used for such experimental purposes. This paper, which was read at the recent Cornwall meeting of the Institution of Mechanical Engineers by Mr. Froude, gives very full particulars of one part of that gentleman's procedure in conducting these experiments; and in order to give our readers some idea of their nature, of the truly scientific manner—the thoroughness, we may say—in which they are carried out, we add some further information of a general character which can be relied on as substantially correct.

When the design of any model which is to form part of the series under trial has been decided on, the first stage in the proceeding is to prepare in hard paraffine a sufficiently large model, which shall have, with the most perfect accuracy attainable, the contemplated lines. The models used are from 9 ft. to 16 ft. in length, displacing on an average probably 600 lbs. each. When the design of a model has been decided on, a rough casting of it is made in the paraffine, and its successive water lines are accurately cut by automatic apparatus, which copies on an enlarged scale those of the design; the copying arrangement being such that the ratio of enlargement in each of the three dimensions is independent of the others, so that several successive models of the one and the same fundamental character, yet differently proportioned in length, breadth, and depth, may be produced from the same design.

This is effected by help of set of templates of adjustable curvature, consisting each of a flexible steel ribbon, set off as a curve from a straight edge by adjustable push-and-pull rods which serve as ordinates. The set when duly combined is in effect a small scale skeleton original of the intended model. The templates and the mode of arranging them are fully described in the paper we reprint. It will be seen that they may either be set to a design already decided on, or employed in completing the design. Each of these templates representing one of the water lines is in turn employed in the shaping machine, and serves as a guide to the cutters as the paraffine casting is caused to travel between them; consequently for each template a corresponding line is cut on each side of the paraffine mass, the rough uncut pieces between the lines being subsequently removed by hand in the manner fully described in the paper. When completed, the model hull is placed in the tank, which is nearly 280 ft. long, by between 30 ft. and 40 ft. wide, and 10 ft. deep, and under cover, so as to be completely removed from atmospheric influences. A light railway is suspended from the framing of the roof, traversing the entire length of the tank at about 20 in. above the normal water level, there being a clear space between the rails, the gauge of which is preserved independently of sleepers. A stoutly framed carriage suspended from two pairs of wheels runs on the railway, and is moved by an endless wire rope, coiled in a spiral groove on an accurately turned barrel, which is driven by a small engine having a heavy fly-wheel and a chronometric governor of very exact action, and of such arrangement that any required steady speed between 100 ft. and 1000 ft. per minute can be assigned by it to the carriage.

This carriage supports the dynamometric towing apparatus to which, after having been loaded to the calculated displacement, the model hull is attached. The method of attachment at both stem and stern is such that while the model is perfectly free to move in any direction in a fore-and-aft vertical plane, no lateral deviation whatever is possible. This removes one difficulty which would otherwise exist, for it has been found that whenever it is attempted to tow a model by a single attachment, it invariably disposes itself at an angle to the line of force, even when the point of attachment travels rigidly in a straight line. The extensions of the dynamometer spring, which constitute a measure of the model's resistance, are brought to an enlarged scale by a lengthened index arm, and are self-recorded by a pen which traces a line on a sheet of paper carried by a cylinder put in rotation by a band from a pulley on the hinder axle of the carriage. Thus the circumferential travel of the paper represents on a small scale the forward motion of the truck. A second pen, actuated by a clock, marks given intervals of time on the paper, so that the marked paper supplies information as to the resistance experienced at each point in the run, and also as to the speed at which each portion of the run was performed. Moreover, as the lines of floatation of the model at rest and in motion are different, the vertical elevation or depression at the stem or stern are also recorded by separate pens. And lastly, a careful observation of the configuration of the waves caused by the models in passing is taken by an assistant who stands in a kind of immersed box or well, so that his eye is but little above the level of the water, the sides of model being graduated so as to facilitate the observation.

The series of results obtained at various speeds with each model is graphically represented on a sheet of paper, and constitutes what is termed the "diagram" for that model, containing:—

(1) The "curve of resistance," a figure in which the base line gives the speeds; the ordinates, the corresponding resistances.

(2) A pair of curves shows the alteration

in level of the head and stern at the various speeds.

(3) Carefully drawn representations of the wave profiles.

So much for the experiments with the ship; the behavior of the screw is recorded by other apparatus. For this purpose also a travelling carriage is employed, running on the same rails, but with some interval between it and the former. This carriage is connected with the towing carriage by means of a rigid coupling bar, and consequently the two travel at precisely the same speed. The screw is fitted on the end of a horizontal bar or shaft immersed below the carriage, the end of which projects far enough forward to carry the screw—if required—in its natural position under the model's stern, yet quite independently of the model; or, by varying the length of the coupling bar, at any given distance astern of that position. The screw receives its rotation by a belt from an axle of the truck, and can be "speeded" at pleasure. The carriage of the shaft bearings is a rocking frame, delicately hung, so as to possess an equilibrated parallel motion in a fore-and-aft plane; and the "thrust" of the screw, which forms a forward drag on the frame, is dynamometrically self-recorded; so also is the driving force of the band which gives motion to the screw shaft, as well as the "count" of the screw's revolutions.

By experiment, such a speed is assigned to the screw that its thrust equals the model's actual resistance.

The object of this part of the apparatus is to determine the virtual increase of resistance which is occasioned by the rotation of the screw close to the "run" of model or ship, which diminishes very sensibly the pressure of the water there, and thus in effect very sensibly augments the resistance. The augmentation may amount to 30, 40, or even 50 per cent., according to the fulness of the run and the closeness of the screw to it. The curves of resistance often present curious and rather abrupt variations in the law of resistance in terms of speed, depending apparently on the modifications of the wave configurations which change of speed induces, and which vary characteristically for each individual model.

The circumstance which — according to the views which Mr. Froude has propounded—gives value to experiments with a model, as rendering them capable of true interpretation in relation to the ship it represents, is that the wave configurations will be similar for the model and for the ship whenever their relative speeds are as the square roots of their respective dimensions, or, as Mr. Froude expresses it, are "corresponding speeds;" and that in virtue of this condition it follows that at the "corresponding speeds" the resistances will be as the cubes of the respective dimensions.

This law would have been true on the crude hypothesis which was formerly held, that the resistance of a given form at various speeds was as the square of its speed, and that, comparing small and large similar forms, their resistances were as their respective midship sections. But though, in consequence of the energy expended in the formation of waves, the resistance grows—as has long been known—abnormally as compared with the square of the speed, yet, from the circumstance that the waves generated by similar forms are similar at corresponding speeds, Mr. Froude has shown that the law he proposes holds good under that limitation of speeds.

THE MODERN EUROPEAN STYLE.

BY JOHN P. SEDDON.

From "The Architect."

Having taken an early part in the discussion upon a modern European style, I have watched with interest the recent communications to this Journal on the subject. There seems as little unanimity of opinion in them as there is in professional practice of the day, but one and all unite in condemning or damning with faint praise the character of the buildings of the day, upon which pretensions or hopes of an existing or future modern European style are based.

They have but one characteristic, viz., impurity. Let us drop for the nonce all questions of rival styles. There are no such things. Architecture, while a living art, was a sequence, a chain, the separate links of which we may group as styles for our own convenience to assist memory. First, we see in the remote ages, in the far East, a luxuriance of ill-regulated ornamentation and ponderous unscientific construction, aiming at producing imposing effect by the coarsest and least economical means—size and elaboration. Egypt, Assyria, and Persia thus wrought stupendous works, which formed the quarry for the later architecture of the civilized world. The Greeks founded the art of architecture out of their elements, and in their Doric temple created the Classic order, *par excellence*, for works of imposing dignity. But even this was on a moderate scale as compared with what should be the modulus for terrestrial work—the height of a man. The less logical but more graceful Ionic, and the pretty Corinthian, in their hands, were for lighter and smaller and more decorative works.

Perfect for what it was intended for, but radically external architecture, created for display not use, to be looked at and not dwelt in, Greek architecture is a dead art —like the Classic language—to be studied as models of good proportion, harmony, and the like principles.

The Romans built well and grandly, and foreshadowed in their construction all the "true principles" which formed the characteristics of Mediæval architecture. The Greek had been only trabeate architecture. The Romans built round arches, barrel and groined vaults, but did not see the drift of what they were doing, not being artists. They got the subdued and corrupted Greeks to case their constructions with orders, piled one on the top of another, and destroyed all the consistency of Classic architecture.

Mediæval architecture was but the common-sense use of the same materials, modified to meet new wants. It was but the same art, only no longer used, as by the Greeks, wholly for external show, nor as by the Romans as a mask. It grew naturally out of the plan of the buildings and their interior structure; it was the logical outcome of the round arch, grafted upon the trabeate system, which the Romans had failed to achieve; but the necessities of vaulting compelled the use of the pointed arch, and the Gothic was the necessary result of that more scientific invention.

This is the history of living architecture. Why then are we, who are the heirs of all ages, to go back to an early phase of this sequence? Why should we voluntarily abandon any invention science has given us?

I might have gone on to show how trabeate architecture was the child of the South, where light was not needed and snow is not known; and that the Northern development of Gothic was framed to admit light, and shunt off snow and rain. But what is this but to say that the art of architecture, when living, met every requirement of time and climate? I may ask, however, why we should deliberately go back to any phase of the sequence which was specially suited for other circumstances than our own?

If we have to contrast the two great divisions of the history of architecture—Classic and Mediæval—the essential difference is, not that the one is trabeate only and the other arcuate also, but that the one is what Mr. Henry Conybeare calls *exothenic*, that is, built from without, and the other *esothenic*, that is, built from within; but Greek architecture is true, and the Roman is false *exothenic*.

Now when the career of living architecture was over, and copyism took its place, men reverted to this system of designing the outside first, and unfortunately also to the making this outside architecture a sham.

Architecture became *architecturesque*, that is, it looked like architecture, but was not. It became pinafore architecture, of which there are no styles, but fashions only. True architecture struggled long with it, elsewhere than in Italy, and the Tudor, Elizabethan, Jacobæan, and Queen Anne styles had successively less and less of the true, and more and more of the false. As Professor Kerr described the last-named fashion, it was "the picturesque art of a most unpicturesque time." But whence came the picturesqueness—its one claim to our regard, save delicacy in detail, for which the Classic revival may be credited? Whether is preferable, the general design or its detail? Inigo Jones and Sir Christopher Wren removed the last remnants of the true architecture, and introduced that of the mask—the architecture of dressings. What would the Banqueting Hall at Whitehall, by the former, be without its dressings? what St. Paul's Cathedral without its mask—the whole upper order which hides the roof?

Granted their proportions are good, that is in the former case those of the dressings, for the building is but a square box without them. But we want the buildings before proportions, we want convenience before regularity.

The discussion now seems to be wholly as to the art of architecture on the supposition of the possibility of its severance from the construction. Let the art take care of itself, as it will do in the hands of an artist.

Several of the disputants are unnecessarily complimentary to each other. Courtesy is well, but it should not blunt the edge of weapons in war. I said I agreed with Mr. White, but I could not have understood him. He seems to talk of Gothic as obsolete, and fancies we are coming to Neo-Greek. What, give up the arch and go back to the trabeate! We should then be on a backward track, which, if our dress is to be assimilated, would lead us to the fig leaf.

What we want to return to is pure common-sense architecture. Never mind its name—architecture that first makes a good plan and sound construction, and which abhors a mask that puts no feature not necessary, but makes those beautiful that are necessary. Can this be done with revived Italian? I should rejoice to be shown an example, and then might adopt the style at once. But Italian architecture, without its dressings and reduced to common-sense, what is it? As Mr. Street says, it is just the one step further from Queen Anne to Harley Street. Take Sir G. G. Scott's Foreign Office; architecturesque considerations have made him try to make a five-storeyed building look like a three-storeyed one, and so the lighting of the interior has been sacrificed. Italian regularity of the outside has made a hash of the requisite irregularities within.

Last week I went over a new Italian public structure with centre and wings, imposing enough outside, but I was told over-windowed for its purpose, but that the elevation required. I asked if the apartments were calculated for their use, and was told, not at all; but then that was necessary to make the wings agree. This may be architecturesque, but it is not architectural.

Professor Kerr thinks that we are coming to something suitable to this age, and Mr. Roger Smith anticipates that regularity is what the age is aiming at. How we are to come out of the slough of architectural impurity we are in with clean hands, I cannot see; there is not a feature of Classic architecture not daily murdered before our eyes by those who pretend to reverence it. If there be anything in the proportions of the orders, how can buildings which violate every one of them advance their interests? Regularity is certainly in vogue with the vulgar and with speculating builders; and the rows of terrace-houses of the latter are models of symmetry. The real fact is, this love of regularity is but another form of the canker which destroyed Classic architecture —the attention to the exterior before that of the interior. Let regularity come if it list, as the Gothic architects allowed it, while they refused to be its slaves. Witness the Town Halls in Belgium.

Architecture does not consist in details, so let styles which are known mainly by them be set aside. Let us return to the best phase of past art looked at as a whole, the most comprehensive and scientific, and build in that, and put a prohibitive tax upon dressings. We should soon then see, as Mr Street has put, by men's work what is in them.

CONDITIONS WHICH DETERMINE AND AFFECT THE DEVELOPMENT OF FORCE FROM EXPLOSIVE AGENTS.

Proceedings of the Institution of Civil Engineers.

The degree of rapidity with which an explosive substance undergoes metamorphosis, as also the nature and results of such change, are, in the greater number of instances, susceptible of several modifications by variation of the circumstances under which the conditions essential to chemical change are fulfilled.

Excellent illustrations of the modes by which such modifications may be brought about are furnished by gun-cotton, which may be made to burn very slowly, almost without flame; to inflame with great rapidity, but without development of great explosive force; or to exercise a violent destructive action, according as the mode of applying heat, the circumstances attending such application of heat, and the mechanical condition of the explosive agent, are modified.

The character of explosion and the mechanical force developed, within given periods, by the metamorphosis of explosive mixtures such as gunpowder, is similarly subject to modifications; and even the most violent explosive compounds known (the mercury and silver fulminates, and the chloride and iodide of nitrogen) behave in very different ways, under the operation of heat or other disturbing influences according to the circumstances which attend the metamorphosis of the explosive agent (*e. g.*, the position of the source of heat with reference to the mass of the substance to be exploded, or the extent of initial resistance opposed to the escape of the products of explosion). Thus, chloride of nitrogen, when covered with even a thin film of water, explodes with great violence when brought into contact with a decomposing agent; but if the covering of water is entirely removed, and the usual means are resorted to for causing the instantaneous decomposition of the liquid, its transformation into gases takes place with little or no explosive violence. Again, if a heap of fulminate of mercury be ignited at any portion of the exposed surface or immediately beneath it, the substance inflames with a dull explosion, and but little mechanical work is performed; but if the heap be ignited in the centre, or near the base, the explosion is very violent, and considerable shattering effect is produced. In these instances, the covering of the water, on the one hand, and the external portions of the heap of fulminate, on the other, perform the functions of the tamping in a blast-hole, or of the walls of a shell, in determining accumulation of pressure and consequent development of violent explosion at the point of first ignition, which is then instantaneously transmitted throughout the mass. Applying this result to practical purposes, it is found that by igniting a charge of powder at or near the base in an ordinary blast-hole, considerable destructive effect can be developed without the use of any tamping, as the upper portion of the charge acts itself as tamping to the part first ignited, and develops its violent explosion. The destructive action is, of course, still further increased if tamping be employed under the above conditions.

Nitroglycerine and analogous explosive compounds, which bear some resemblance to chloride of nitrogen in their power of sudden explosion, require the fulfilment of special conditions for the development of their explosive force. Thus, the explosion of nitroglycerine by the simple application of heat can only be accomplished if the source of heat be applied in such a way that chemical decomposition is established in some portion of the mass, and is favored by the continued application of heat to that part. Under these circumstances, the chemical change proceeds with rapidly accelerating violence, and the sudden transformation, into gaseous products, of the heated portion eventually results—a transformation which is instantly communicated throughout the mass, so that confinement of the substance is not necessary to develop its full explosive force.

The same result can be obtained more expeditiously, and with much greater certainty, by exposing the substance to the concussive action of a detonation produced by the ignition of a small quantity of fulminating powder, closely confined and placed in contact with, or in proximity to, the explosive compound.

The development of the violent explosive action of nitroglycerine, freely exposed to air, through the agency of a detonation, was for some time regarded as a peculiarity of that substance; it has, however, been demonstrated that gun-cotton and other explosive compounds and mixtures do not necessarily require confinement for the full development of their explosive force, but that this result is attainable (and very readily in some instances, especially in the case of gun-cotton) by means similar to those applied in the case of nitroglycerine.

The manner in which a detonation operates in determining the violent explosion of gun-cotton, nitroglycerine, etc., has been made the subject of careful investigation. It has been demonstrated experimentally, that the result cannot be ascribed to the direct operation of the heat developed by the chemical changes of the charge of detonating material used as the exploding agent. An experimental comparison of the mechanical force exerted by different explosive compounds, and by the same compound employed in different ways, has shown that the remarkable power possessed by the explosion of small quantities of certain bodies (the mercury and silver fulminates) to accomplish the detonation of gun-cotton, while comparatively large quantities of other highly explosive agents are incapable of producing that result, is generally accounted for satisfactorily by the difference in the amount of force suddenly brought to bear in the different instances upon some portion of the mass operated upon. Most generally, therefore, the degree of facility with which the detonation of a substance will develop similar change in a neighboring explosive substance may be regarded as proportionate to the amount of force developed within the shortest period of time by that detonation; the latter being, in fact, analogous in its operation to that of a blow from a hammer, or of the impact of a projectile.

Several remarkable results of an exceptional character have, however, been obtained, which indicate that the development of explosive force under the circumstances referred to, is not always simply ascribable to the sudden operation of mechanical force. These were especially observed in the course of a comparison of the conditions essential to the detonation of gun-cotton and of nitroglycerine by means of particular explosive agents (chloride of nitrogen, etc), as well as in an examination into the effects produced upon each other by the detonation of these two substances. In illustration, it may be instructive to give two examples. The detonation of compressed gun-cotton is accomplished by the explosion of 5 grains of confined fulminate of mercury, placed in contact with the mass, but it requires ten times that quantity of the violent explosive agent, chloride of nitrogen, also confined, to produce the same result. Again, the mechanical force exerted by the explosion of nitroglycerine is fully equal to that developed by the fulminate of mercury, yet a quantity of nitroglycerine, about seventy times greater than the minimum of the fulminate required to detonate compressed gun-cotton, fails, when exploded in contact with the latter, to produce any other result than the complete mechanical disintegration of the mass.

The explanation offered of these exceptional results is to the effect that the vibrations attendant upon a particular explosion, if synchronous with those which would result from the explosion of a neighboring substance in a state of high chemical tension, will, by their tendency to develop those vibrations, either determine the explosion of that substance, or at any rate greatly aid the disturbing effect of mechanical force suddenly applied; while, in the instance of another explosion, which develops vibratory impulses of different character, the mechanical force applied through its agency has to operate with little or no aid; greater force, or a more powerful detonation, being therefore required in the latter instance to accomplish the same result.

Instances of the apparently simultaneous explosion of numerous distinct and even somewhat widely separated masses of explosive substances (such as simultaneous explosions in several distinct buildings at powder-mills) do not unfrequently occur, in which the generation of a disruptive impulse by the first, or initiative explosion, which is communicated with extreme rapidity to contiguous masses of the same nature, appears much more likely to be the operating cause, than that such simultaneous explosions should be brought about by the direct action of heat and mechanical force.

With regard to the general manner in which a detonative action determines the violent explosion or sudden chemical disintegration of such a substance as gun-cotton, the similarity of its operation to that of a blow is readily demonstrated by many and simple experiments; one or two may be mentioned, which have been made with gun-cotton, and which probably illustrate the subject sufficiently for present purposes. The heat developed in a mass, when submitted to a blow, depends upon the resistance which its particles oppose (by reason of its rigidity or solidity) to the motion of the body striking it. Repeated blows may be required to explode a detonating substance placed in the form of loose powder upon an anvil; that force being, at first, in part expended in compressing the particles into a compact mass. When no longer free to move, the resistance they oppose to the force applied determines the sudden transformation of the latter into heat to a sufficient extent to bring about the detonation of the substance struck. If, in the case of gun-cotton, the force developed by a detonation, even of a powerful character, is allowed to operate upon the material in a loose, flocculent condition, the latter is simply dispersed; again, if the gun-cotton be only lightly compressed, a much more powerful detonation is required for its explosion than if it be in a very compact condition; and if the mass of the highly-compressed material be only very small, it cannot be detonated by the means which are successful with larger masses, unless special precaution be taken, by fixing it rigidly to the detonating fuze, to prevent its being dispersed by the force which the explosion of the latter exerts. These facts, when compared with the following experiments, demonstrate that the general action of a detonation in developing the violent explosion of the substance upon which it is allowed to operate is that of a sudden blow given to some portion of a mass, the particles of which are in a condition to resist the motive or dispersive power of the mechanical force applied. A bullet from a Martini-Henry rifle was fired at a distance of about 50 yards against a slab of compressed gun-cotton 0.75 in. thick and 3.75 in. in diameter (weighing four ounces), freely suspended in air by a string; the gun-cotton was simply perforated by the bullet.

A similar result was several times obtained with slabs of gun-cotton of the same dimensions, and with others double the thickness. On making the experiment with a slab of three times the thickness, the gun-cotton was inflamed but not detonated by the impact of the bullet. The mass was in this instance of sufficient thickness to offer considerable resistance to the penetrative power of the bullet; the passage of the latter was therefore retarded to such an extent as to give rise to the heating of the opposing gun-cotton particles up to their inflaming point. This experiment was repeated with the same result; but when a bullet was fired against a piece of compressed gun-cotton four times the thickness of that first employed, and weighing one pound, the result was detonation of the mass.

It need scarcely be stated that the detonation of a large quantity of an explosive body is accomplished by the initiative detonation of a very small portion of the mass; this is the case even if the material is arranged in the form of a train of considerable length, the detonating fuze being applied at one extremity. Rows of gun-cotton disks, from 3 to 5 ft. in length, with intervals of 0.5 in. and 1 in. between the individual masses, have been detonated in this way. There is, however, a limit to the distance to which a detonation will be transmitted along a row of spaced disks, the limit being determined by the particular weight of the masses employed; if it be exceeded, those masses which are at the farther extremity will be inflamed and scattered, instead of being detonated. A few preliminary experiments have been made with the view of determining, by means of Noble's chronoscope, the rapidity with which detonation progresses along a row of gun-cotton disks. This will, no doubt, vary with the sizes of the masses. In an experiment with disks weighing two ounces each, placed in a row without intervals, it was found that the detonation extended to 3 ft. in about one five-thousandth part of a second.

THE DISINTGERATION AND UTILIZATION OF SLAG.

By C. CLAUS.

From "Iron."

After the discussion on the above subject, which lately took place at the Cleveland Institution of Engineers, the Secretary received a very interesting letter from M. C. Claus, from which we extract the following:

The application of slag as a manure has been proposed, and even patented repeatedly, a long time since, and especially at a time when the chemical rationale of its value and use as such was least understood. Practical results of its application alone must, therefore, have given rise to this suggestion. The large percentage of lime seems to have been considered the active principle of its efficacy. Mr. Wood himself, even in his former paper, read before another Society, stated that on account of the large quantity of lime the slag contained, it must be considered of great value as a manure, and in a paper shown to me by Mr. Wood, since the reading of his paper, Dr. Volkner, the consulting chemist to the Royal Agricultural Society, is made to say that slag appeared to be a good substitute for lime as manure.

Believing, as I do, to have been instrumental in directing Mr. Wood's attention, previous to the reading of his last paper, to the real source of value of slag as a manure, viz., to the silica in its readily soluble, and for plants, easily assimilative form, I feel bound to second the statements made by him in that sense.

In doing so I shall attach my remarks on the subject to the assertion by Mr. Gjers, that soil already containing 60 per cent. of silica required, not the addition of another silicious substance like slag (containing only 38 per cent.) as a manure. I beg to state that there is, perhaps, no soil more needy of silica, in the form in which it exists in slag, than a soil consisting of pure quartz sand, and containing, we will say, for the sake of illustration, 100 per cent. of silica.

Not any more logically than that a bag full of silica, clay, lime, and soda, constitutes so many dozen of glass bottles, does it follow that the existence of 66 per cent. of silica in soil is sufficient for the nourishment of plants. There are several forms of silica, some of which (such as pure quartz sand) are utterly unavailable to plants as a source of silica. Silica in its form as free silica, even in its gelatinous and otherwise soluble state, seems to be of little service to plants. Only when in combination with bases (especially lime, alumina, and potash) separable therefrom by weak acids, seems to be the form in which plants can take it up. Amongst its combination with bases, there are only a few which are readily available for plants, owing to their not being easily decomposed by highly diluted aqueous solutions of carbonic acid, and perhaps of carbonate of ammonia (the products of the decomposition of animal and vegetable matter). There is also a most remarkable difference in the degree of solubility of silicates of equal compositions in the above named re-agents—some are utterly insoluble therein, whilst others are. Others again, some clays, for instance, at first little soluble in highly diluted acid, when mixed with cream of lime, thicken, and are found to become much more soluble after such treatment; hence the explanation of the utility of burnt lime, as a manurial agent. Burnt lime is not so much a manure in itself (for there is plenty of carbonate of lime in most soils), as in acting by dissolving and opening out to the use of plants the silica, in combination with alumina, and the alkalies.

Plants containing in their ashes and requiring for their growth large quantities of silica, cannot be grown successively in the same field. The land has to be laid in fallow, in order to accumulate the amount of soluble silica, as the process of dissolving it, being in the ordinary course of things a very slow one, does not keep pace with the requirements of the plants which take up other mineral constituents in the meantime much more quickly.

Lands, otherwise well manured, but deficient in soluble silica, will grow, for instance, good and rich-looking crops of wheat, with even well-filled ears, but the straw is too weak to bear up the ear, and it therefore lies down on the ground. A remarkable instance of this was shown to me by a farmer in Yorkshire, about twelve years ago. A rich-looking field of corn in full ear was all laid down on the ground. In the midst of this stood a square patch of equally rich-looking corn, perfectly erect. The straw of the latter was found to be richer in silica than that of the former. This peculiar occurrence could not at first be accounted for, but on closer inquiry it turned out that two years previously a clamp of bricks had been burned on the spot. When silicates are intimately mixed with lime or alkalies and then submitted to the action of a strong heat, a change takes place in the condition of the silica—it enters into that condition which makes it more quickly available for plants. This is exactly what had taken place with the soil on which the brick clamp had stood, and in the Middlesborough slag we have this action to perfection.

Liebig, who was the first to show the importance of the part played by silica, in this soluble form, for the economy of plants, says, in one of his works (I forget in which), that the time may come when the agriculturists will import as a manure the mineral "Palagonite" from Iceland, in the composition of which the silica is held in so loose a state of combination that it will readily become separated even by weak organic acids. In this respect it resembles closely Cleveland slag, which also gelatinizes easily with weak acids. But our slag has, besides this chemical property, most valuable physical qualities, which especially fit it for a manure, and these it obtains when it becomes disintegrated by being run into water whilst in a fluid state As Mr. Wood stated, it becomes thereby converted into a mass of finely walled hollow cells, which offer innumerable points of attack to the plants feeding upon it. I consider it, for this reason, a most valuable silicious manure applicable for almost every kind of soil, and it is my opinion, that by the proper use of it, consecutive crops of wheat could be grown, year after year, on the same land, provided the other supplementary manures are supplied abundantly as well.

I recommended the spongy water-disintegrated slag two or three years ago, to a firm of owners of sugar plantations for their use, after having been consulted by one of the persons connected with the firm as to the possible cause of disease in the cane, which had shown itself to be steadily on the increase during the last few years. The sugar-cane requires large quantities of silica for its growth, and it has been the practice for years past to burn the spent cane as fuel, and to waste the ashes. The land had thus become so impoverished of assimilative silica, that it no longer did its duty. I am sorry to say they did not avail themselves of my recommendation, else Middlesborough might now be doing a good trade in slag with the West Indies.

The exceedingly porous form of the water-run slag offers other conditions favorable to the subtle agencies at work in the growth of plants.

Allow me, in conclusion and self-defence, to say a word or two in reference to the statement made by Mr. Wood, when showing the specimens of tiles and slabs made by my patent process from the slag. He said they were splendid specimens, which compliment I will receive with thanks, but he said also that the process of manufacture was expensive. Considering that the materials and operations connected therewith are so much like those in the process by which he says that bricks can be made for 12*s.* per 1000, I cannot see where he can find the source of expense. I mix disintegrated slag with about 20 per cent. of common brick clay intimately, mould the mass in a brick machine or by hand into bricks, and, if pressed goods are wanted, press them, then dry for two or three days, and burn them. In the Slag Working Company's process, they mix intimately disintegrated slag with lime (instead of my brick clay), mould and press, and then dry in the air for two or three weeks. Where now is the difference in cost, except in the burning? As offset against this, I have common clay against their lime.

THE INFLUENCE OF ACIDS ON IRON AND STEEL.*

From "The English Mechanic and World of Science."

He said Professor Reynolds, in an interesting paper "On the Effect of Acid on the Interior of Iron Wire," appears to think that I did not attribute to hydrogen any portion of the remarkable change produced in iron and steel by immersion in acid. That immersion in acid is the primary cause no one, I think, will dispute; but that hydrogen plays an important part in producing these changes and is the cause of the bubbles, the following paragraph from a paper I read before the Society, March 4th, 1873, will prove: "The experiments of Professor Graham in 1867, and more recently those of Mr. Parry, show that hydrogen, carbonic oxide and carbonic acid, and nitrogen are evolved from wrought iron, cast iron, and steel when heated in vacuo. Therefore it seems probable that a part of the hydrogen produced by the action of the acid on the iron may be absorbed by the iron, its nascent state facilitating this. And when the iron is heated by the effort of breaking it, the gas may bubble up through the moisture on the fracture." The supposition that the absorption of hydrogen is the sole cause of the change in the breaking strain, diminution in toughness, etc., attendant on the immersion of iron hydrochloric or sulphuric acids, and that there is no absorption of these acids into the interior of the iron, does not account for the following phenomena:—1. The gain in weight of a piece of iron by immersion in hydrochloric acid is less than by immersion in sulphuric acid, as is proved by experiments described in my first paper on this subject. 2. Iron after immersion in hydrochloric acid sooner regains its original state than after immersion in sulphuric acid. 3. If acid iron, *i. e.*

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* A paper read before the Manchester Philosophical Society by W. H. Johnson.

iron which has been immersed in hydrochloric or sulphuric acid, be steeped in an alkaline solution it sooner regains its original state than with immersion in water alone. 4. Take two pieces of iron alike in size and quality, and immerse one in hydrochloric acid and the other in sulphuric acid for some hours, then wash them well in water and dry them gently, and leave them in a temperate room for some hours more. At the end of that time it will be invariably found that the piece which was in hydrochloric acid is covered with a dark-brown red oxide of iron, while the piece which was in sulphuric acid will be only slightly rusted. 5. Litmus paper when applied to the moistened fracture of acid iron is slightly reddened. All the above phenomena have been observed so often and so carefully as to leave no doubt of their invariable recurrence if the conditions of experiment be only properly observed. It seems to me that the only satisfactory way of explaining all the phenomena is to suppose that when a piece of iron is immersed in acid two actions go on, viz., an absorption of the nascent hydrogen into the interior of the iron, which hydrogen may subsequently be given off by gentle heat or immersion in a liquid, etc.; secondly, an absorption of the acid itself, possibly in a very concentrated form, by the insterstices between the fibres or crystals of the metal. That it is possible for a liquid to pass into the interior of a piece of iron is, I think, proved by the sweating of the cylinders of hydraulic presses, and also the known diffusion of gases through iron.

The structure of iron as revealed by the microscope and the changes it undergoes during manufacture, by which a spongy mass is by hammering and rolling squeezed together, all go on to prove that there are numerous cavities in iron and steel. It will, however, be said the acid must act on the walls of the cavity and form a salt of iron with liberation of hydrogen. This may go on to a small extent, but in opposition to this view we may bring the experiments of Professor Bequerel on solutions separated by a cracked tube ("Comptes Rendus," LXXVI.), where he shows that no precipitate is formed on placing a cracked tube filled with nitrate of lead in a solution of potassium sulphate within the crack, thus making it probable that chemical interchanges do not take place in very minute spaces. By this theory we may easily explain the decrease in toughness after immersion in acid, for toughness implies a certain ease of mobility of the particles. When a piece of iron is bent, the particles of one side are compressed, thus diminishing the minute cavities between the fibres; while those of the other side are stretched, and the minute cavities elongated. Now if we fill these cavities with a liquid, this mobility of the particles is prevented, for the cavities cannot now be diminished in size, and the compression of the one side cannot now take place; consequently the piece tears or breaks off just like a piece of frozen rope. It will also explain the acid reaction of the moistened fracture; and further, as hydrochloric acid is much more volatile and of less specific gravity than sulphuric acid, it is only natural to expect that the effect of immersion in hydrochloric acid will pass off more rapidly than of immersion in sulphuric. This, experience fully confirms. With a view of determining these interesting points a number of experiments were made in the following way, viz.:—Small coils of iron wire were immersed in hydrochloric and sulphuric acids for different lengths of time, and then carefully tested for tensile strain in a very accurate machine, so constructed that the elongation of the wire while under strain could at any moment be ascertained. The weights could also be added quickly and without imparting any shock to the wires, points to which great importance should always be attached in experiments of this kind, as a slight shock or jar on the addition of a weight will often cause the rupture of a piece which otherwise would have stood a much higher strain. The length of the pieces tested was in all experiments 10 in. between the dies of the machine, and their temperature at the time of experiment about 16 deg. C. After the ultimate elongation and breaking weight had been ascertained with this machine, the coils were placed on warm plates or in hot chambers for some hours, and subsequently tested in the same way.

Experiments were made in this way, and lead us to the following conclusions:—1. That immersion in hydrochloric acid for one hour diminishes the tensile strain of annealed iron 297 lbs. per sq. in. of section; the tensile strain of unannealed iron 2,389 lbs. per sq. in. of section, and diminishes the ultimate elongation of annealed iron 0.8 per cent.; ditto, unannealed iron, 0.38 per cent. 2. That immersion in hydrochloric acid for six hours diminishes the tensile strain of annealed mild steel 2,563 lbs. per sq. in. of section, and increases the ultimate elongation of annealed mild steel 4.7 per cent. When first I discovered that a decrease of ultimate elongation under strain was the result of immersion of steel in acid, I thought there must be some experimental error, and accordingly carefully selected three coils, all of uniform temper, and made three tests from each coil. The singular regularity of these tests must be said to remove all doubt as to the truth of the results of the first experiment. It then occurred to me that possibly prolonged immersion in acid might so decrease the breaking strain that the wire would not recover its original strength. For this purpose I carefully tested the elongation and breaking strain of the wire before immersion in acid, and again after heating for five days on a hot plate. The results of these experiments confirm this view, showing that there is—1. A permanent decrease in breaking strain after prolonged immersion in sulphuric acid, of 12,205 lbs. per sq. in. of section; hydrochloric acid, of 31,275 lbs.

Both these results are, doubtless, too high, as the surface of the wire was pitted by the acid; consequently its actual sectional area was less than that calculated from the diameter as measured. 2. A permanent increase in the elongation after prolonged immersion in sulphuric acid of 1.7 per cent., hydrochloric acid of 1.17 per cent. Having examined the effect of acid on annealed steel, it was next thought advisable to try the effect on unannealed. This showed that the immediate effect of immersion in acid was to decrease the tensile strain of unannealed steel 4,045 lbs. per sq. in. of section, and increase the ultimate elongation of unannealed steel 2.14 per cent. The change is thus similar to that which takes place in annealed steel. It is, however, interesting to observe that 12 hours at a temperature of 40 deg. to 100 deg. C. not only restores, but actually increases, its original breaking strain and elongation, while a still more prolonged submersion of 7 days to the same temperature still further increases them. These last experiments also show that some considerable time is required to overcome the change produced by the acid. In conclusion, I may say that the numerical results arrived at, though based on experiments conducted with considerable care, must not be taken as more than approximations to the truth, for experimental errors and variations arising from the imperfect homogeneity of structure of all iron falsify the results, and are only lost by multiplying experiments almost indefinitely.

THE PNEUMATIC PROCESS OF SINKING PILES.

By JOHN W. GLENN, C. E.

Written for Van Nostrand's Magazine.

In the April number of Van Nostrand's Magazine, page 361, Mr. Gabriel Jordan, C. E., states: "During the late war between the States, the Confederate Engineer successfully used the process in sinking heavy wooden piles in the Bay of Mobile.

"In many instances these piles were driven 10 and 15 feet in the short space of one minute, through a material that could not be penetrated by piles driven in the usual way."

It was in 1862 that the work referred to was done; and as the method and details of it were proposed by me, and carried out under my personal supervision, probably a description of it, its causes and purposes, will be interesting to the profession.

Then a Lieutenant of Engineers, I was assigned by Gen. Leadbetter, Chief Engineer, to the charge of the outer line of water defences of Mobile Bay, which then consisted of only Forts Morgan and Gaines, both of which were incomplete and incapable of either offering serious opposition to a properly equipped fleet, or of maintaining a siege.

In the work to be then done so that, as far as practicable, Mobile Bay might be sealed against outsiders, that part of the line which presented apparently the greatest difficulties, was the middle ground between Forts Morgan and Gaines, beginning on the west side of the ship channel, thence to Fort Gaines, about two miles.

On this middle ground was an average depth of about 8 feet of water, with a mean rise and fall of the tide of about 18 inches.

This depth of water was sufficient to allow formidable gunboats to enter the bay, to which the two forts, being three miles apart, could offer little opposition, unless the vessels could be retained under fire a sufficient time to give the gunners of the forts their range, and make their fire effective.

The only method my superiors in rank then would consider was obstruction, and as the place to be obstructed was the outlet to that great bay, exposed to every swell of the Gulf of Mexico, through which the tides swept with a current of about three miles per hour, they were sceptical as to the practicability of almost any method, and at one time they had adopted the policy of quietly removing the munitions and surplus guns, reducing the garrisons to a minimum, merely to keep up a show of resistance.

After making a careful examination of the middle ground, I found it for a depth of over 20 feet, except near Fort Gaines, to be a deposit of sand, such as is common to the Gulf coast.

The violence of the storms, insufficiency of the sand as holding ground for anchorage, and the scour it was liable to, rendered chain-booms, cribs, and all usual methods of obstructing, out of the question.

As the bottoms of all war vessels then afloat were wood, it occurred to me that if ten (10) rows of sawyers, none less than 18 inches in diameter, 10 feet apart in each row, the sawyers of one row opposite the intervals of the next, were planted in that sand, not less than 12 feet deep nor more than 20, and then sawed off below the water so as to leave the stumps projecting above the bottom alternately 3 and 4 feet, that if a vessel was to endeavor to drive its way through the 10 rows, it would find itself "piled up" on the stumps with perhaps one or more through the bottom, or, in case of the forcible removal of the sawyers being attempted, the time required would be sufficient to enable the gunners of the forts to disable the vessel attempting it.

At the time, and considering the great width and depth of the ship channel next to Fort Morgan, it was believed that the displacement of water, and opposition to currents offered by the sawyers, would not produce observable results, but the Pelican Island channel, next to Fort Gaines, was, after the sawyers were planted, found to have scoured nearly two feet deeper.

Owing to the attacks of the "Teredo Na Valis," the sawyers would not have constituted an obstruction over one year, but when the limit of usefulness of one system was reached, another could be planted.

I submitted my views, togther with the description of the manner of planting the sawyers by pneumatic pressure, and, in order to carry on the work expeditiously, asked for two steamers—the two steam fire engines of the city of Mobile, with complements of firemen, teams, and laborers, to procure the sawyers from Dauphine Island, adjacent to the work.

The steamers Dick Keys and Natchez were selected. Amidships, and just after the boilers on each steamer, a steam fire engine was placed, and bolted to the deck.

The steam-chest of the steam fire engine was connected directly with the boilers of the vessel by an inch pipe, and communication with its own boiler broken.

Small shears were erected amidships, which lead outboard sufficient to clear the vessel. From their head was suspended five pulley blocks and falls, for handling the sawyers.

About 50 ft. of hose and an ordinary 1¼ in. fire nozzle were attached to the air chamber, while the suction hose was passed out into the sea water. Each steamer would take on deck from twenty to fifty sawyers, varying from 18 to 30 in. in diameter, generally; though in one instance one of 48 in. in diameter was planted, and a great many between that and 30 in.

The ebb tide, at its greatest velocity, was selected as the time to make the beginning, and the Natchez was brought to anchor on the ground with about 100 fathoms of chain out and a kedge off her starboard quarter, with about 50 fathoms of 5 in. hawser out.

A sawyer was now swung by it, head to the shears; at its lower end two iron staples were driven, in which the brass nozzle was placed, and from the point of the nozzle, and outside the staples, a strand of tarred yarn led to the hands of the director, who controlled the movements of the engine, etc. The sawyer now hung suspended from the shears; a sufficient number of men had hold of the falls to control the sawyer; the director had hold of the yarn, with which he kept the nozzle in the staples, and the engineer stood at the engine, ready to start it when directed.

By the after capstan the hawser was now heaved in sufficient to bring the steamer quartering to the current which brought the chain and hawser both taut for a minute, perhaps. The instant the vessel settled, the steam fire engine was started, and as soon as a stream of water began to flow through the nozzle, the sawyer was lowered and settled in the sand at the rate of about one foot per second. When the requisite depth was attained, the director let go the yarn, seized the hose and pulled its nozzle; the engine was stopped, and by this time the sand had settled to within two feet of its original surface, and the sawyer was immovable.

After the first five sawyers were planted the steamers were moored to them, and, guided by them, moved ahead in the line of the work. After the first day or two the men became so adept that the work progressed very rapidly, even when there was a light swell on.

Over (5,000) five thousand sawyers were in that manner planted, when I was transferred to more important duties in the field.

The machinery and arrangements were the best obtainable in a country then cut off from the balance of the world; not by any means the best, with time and abundant resources for preparation.

The application of pneumatic pressure to sea-coast work first took definite shape with me in 1853, and was first applied by me in 1855, and I expect, eventually, to see it become a leading feature in preparation and giving fixedness to jetties, which must ultimately exercise great influence upon the shallow entrances to our Gulf harbors, the prominent features of which are this same sand.

WHAT IS FIRE-PROOF CONSTRUCTION?

From "The Building News."

The heavy losses recently sustained by a large number of individuals among the "upper ten thousand" by the disastrous conflagration in Belgravia has directed public attention to the discussion of the subject of fire-proof construction, and has led many to doubt whether it is possible to erect a large building capable of resisting the ravages of fire. And this doubt is almost converted into a certainty when they discover that most of the great fires which have occurred within recent times have been in buildings designated "fire-proof." The extensive warehouses in Tooley street, which were destroyed by fire in June, 1861, and in endeavoring to extinguish which Mr. Braidwood lost his life, were constructed on what are termed "fire-proof" principles—namely, with floors formed of brick arches upon iron girders and iron columns. Yet we find that these warehouses, extending over three acres of ground, and containing goods valued at over two millions sterling, were as entirely destroyed as if they had been built of wood. More recently has occurred the destruction of the City Flour Mills, in November, 1872, in which the floors were of stone flags laid on iron joists, resting upon iron girders, and supported by iron columns—a mode of construction which was thought to be perfectly fire-proof, since no part of it could burn. We have also seen how the "fire-proof" construction failed at Paris, in 1871, when the Communists burnt down a large portion of that city. We have, therefore, placed before us the serious question, and one that it behooves an architect to be able to answer satisfactorily—namely, What is fire-proof construction?

There appears to be in the minds of most ordinary persons, and indeed of many practical men, a considerable amount of confusion between materials that are incombustible, and those which are fire-proof. The former term is applicable to all materials which will not take fire or blaze up when subjected to great heat, or which can never be made to act as additional fuel to the flames—such as stone, brick, concrete, iron, cement, plaster, tile, slate, glass, and several hard woods. Only a few, however, of these can be properly called fire-proof, or capable of resisting without change the action of intense heat. Among the great variety of building stones but few can be considered fire-proof; limestones are readily calcined and converted into quicklime by the action of fire, so that Portland stone staircases are considered by London firemen as far more dangerous than ordinary wooden ones, as they snap off and fall in a mass as soon as the flames touch them. Yorkshire flagstones will split to pieces by the action of fire; but there are many good building stones in Yorkshire, called by geologists the "grits," which are capable of withstanding great heat. These are, however, comparatively little known to London architects. There are also the grits of Scotland, such as Cragleith stone, and many others which may be considered as fire-proof. Granites are not so fire-resisting as their igneous origin would lead us to expect; but they are capable of withstanding a considerable heat unless suddenly acted upon when hot by a jet of water. There are several kinds of artificial stone now made which are far more fire-proof than most of the natural stones. Concrete may be considered as an artificial stone; but if made with broken limestone it will not be fire-proof; the materials used with the cement must be either sandstone pebbles, such as are found in gravel, flints, broken brick, or burnt clay. Slates are not by any means fire-proof, as they split to pieces under the action of fire. All the harder kinds of brick and tile may be generally considered as capable of resisting fire when used as walls, or as arched floors; but the softer kinds crumble when highly heated, especially if water should happen to touch them. Bricks made of fire-clay are the best that can be used in forming fire-proof structures. Iron becomes so much weakened when highly heated that it can hardly be looked upon as fire-proof, unless protected by some non-conducting substance; it is found, however, that solid cast-iron columns will stand heat far better than hollow ones, and as they take up less room, they might easily be protected by a coating of cement or other material, without occupying more space than hollow columns of the same strength would do. Cast-iron girders soon give way if heated and then cooled by a jet of water, and wrought-iron beams twist and thrust out or pull down the walls, so that unless well protected they must never be used in buildings professing to be fire-proof. Although glass cannot be made to take fire, yet it breaks into pieces as soon as the heat reaches it, and liquefies at a moderate temperature.

Hence it appears that the number of materials for construction which may be considered fire-proof is very limited, and that it depends in a great degree upon the manner in which these are used whether the building is fire-proof or not. Many of the harder kinds of timber, if used in large scantling, may be considered as fire resisting; the effect of heat does not penetrate into the interior of the wood, and only chars the outside; but when timber is cut up into thin slices as joists or rafters, it readily ignites, and adds fuel to the fire.

We will now consider what are the best modes of employing the few materials which are really fire-proof in the construction of buildings so as to render a great conflagration almost impossible. In the first place, we must look at the purposes to which a building is to be applied, as the same construction may be perfectly fire-proof in one kind of edifice but not in another. The construction of S. Thomas's hospital, for instance, with iron girders and concrete arches for the floors and ceilings, is thoroughly fire-proof, so long as it is used only as an hospital; but suppose it should at any future time be converted into a warehouse for the storage of such inflammable articles as jute, cotton, oil, tallow, or saltpetre, as was the case in the great "fire-proof" warehouses in Tooley street burnt down in 1861, there is hardly a doubt that if a fire broke out in any part the total destruction of the whole block would be inevitable. We might say the same of the handsome banking house recently illustrated in our pages, in which a similar construction is employed; and as there is no great amount of inflammable material in either building as at present used, no very great heat would be produced if a fire did occur in any one part; hence it is clear that both these edifices may be deemed practically fire-proof, except under extraordinary circumstances such as occurred at the fires caused by the Communists in Paris in 1871. Ordinary dwellings may be rendered sufficiently fire-proof at moderate expense by avoiding the use of materials that readily catch fire, such as thin joists and rafters, and light balusters to the staircases; by putting thick joists to carry the floors and pugging between them; by filling up the space under the staircase, between the wooden treads and the plaster soffit; by using iron balusters to the stairs; avoiding quarter-partitions or having them bricknogged, so as to leave no hollow spaces; by having the floor-boards of wainscot instead of deal, and tongued with iron. A very good fire-proof floor can be made by filling between the joists with cement concrete 3 or 4 in. thick, so that the plaster can be laid on the under side without laths, and any sort of floor laid above.

But it is not in buildings of the class we have named that the great fires occur, and which can be rendered practically fire-proof without much difficulty or expense; but in the large warehouses covering acres or even miles of ground in our docks and along our river sides, and in which thousands of tons of inflammable goods are stored. These buildings require a very different mode of construction to render them capable of withstanding the tremendous heat that will be generated if a fire occurs in one of their great rooms. In the first place, the walls of such buildings ought to be made much thicker than the minimum allowed by the Building Act; an extra half-brick or whole brick in thickness would not add much to the cost, and would increase the stability to a very great degree. The brickwork should be protected both inside and outside with cement or plaster materials, which were found in nearly all cases to remain uninjured in the buildings destroyed in Paris in 1871.

Concrete would be a better material than brick for the walls of warehouses, and need not be made so thick as would be required for brick walls, being about one-third or one-fourth stronger; it should, however, have plenty of iron hooping as bond throughout it, so as to prevent settlements and cracks; when this material is used internal plastering becomes unnecessary. Concrete should also be used for the staircases and landings, iron hooping or wire being used to prevent risk of fracture, the steps cast in moulds and built into the walls on both sides, and not made to hang over on the outer side, as is so frequently done. If stone is, however, used for stairs, it should be one of the hard "grits" mentioned above, and free from laminations. Steps may also be made of fire-clay, terra-cotta, or artificial stone, which are both durable and fire-resisting.

For warehouses of large size it is almost impossible to dispense entirely with the use of iron girders to carry the floors; but these must be entirely covered up and protected so as to prevent the fire, should it occur, from touching them. A good way to do this is to lay concrete a few inches thick flush with the underside of the girders, and then cover the whole with common plaster; the floor above can then be laid in any way that is most convenient, as the concrete below will effectually stop any fire from passing through; the concrete should have iron hooping or wire bedded in it. If it be found necessary to support the girders in the middle, hollow iron pillars must be avoided, and they must be either of solid cast-iron or, what would be much better, of fire-bricks moulded circular and built up into a round pillar. If cast-iron is used for the pillars, it should be protected by a covering of fire-brick, concrete, or plaster. The ceiling of the top story should always be made fire-proof, and independent of the roof over it, which may then be made of any ordinary material; for even if the roof took fire, it would not be communicated to the floor below provided a fire-proof ceiling intervened. This is a point that cannot be too strongly insisted upon, at it is generally from the falling-in of the roof that the total destruction of the building follows. The iron girders which carry the floors should not be built into the wall, which is weakened by so doing, but rather supported on corbels of fire-brick or hard grit stone; in either plan, however, the ends must be allowed full play, so that in case of any expansion they may not thrust out the walls. Where an iron bressummer is introduced to carry the weight of a wall above, it must be completely protected in the manner above stated, as any twisting or yielding in the beam will endanger the whole superstructure. A casing of timber plastered over would probably be as effective a means of keeping off the heat from the iron as can be adopted.

The windows of a warehouse form an important feature, and one that must never be overlooked in considering the action of fire. If all the windows and other openings could be kept closed, a fire occurring in a room would soon burn itself out from want of a sufficient supply of oxygen; but in most warehouses there are numerous broken squares of glass which will supply air to the flames and heat up the whole room to the temperature of a blast furnace in a very short space of time. It is useless to have the frames and sash-bars of iron, if the glass is continually being broken;

either very thick glass in small squares should be used, or thin sheets of talc substituted for it.

When warehouses are built in separate blocks, but having openings for communication between them, they are fitted with double iron doors having a space nearly equal to the thickness of the party wall between the two doors. The proper construction of these doors is a very important matter, and the neglect of which has been the cause of many fires extending from block to block, until the whole series are destroyed. If the doors are made of one thickness of wrought iron, that next the room in which the fire originates soon becomes red-hot, and so twisted out of its frame as to allow the flames to attack the inner door, which in its turn gets twisted, and admits the flames to the next block of building. These doors ought each to be made 2 in. or 3 in. thick, and of double sheet-iron, filled in with some non-conducting substance; the bolts of the lock should be made to shoot both ways into the frame in three places, and the frame should be built into the wall, at least, half a brick back from the face, so that the fire can have no effect upon it. If one of these doors becomes red-hot, even on the inner face, no injury will happen to the other door, beyond the scorching of one side. The heads and sills of these doors should be formed either of hard grit-stone, concrete, fire-brick, or artificial stone. Staircases must always be separated by party walls from the several rooms, and should have iron doors to close the openings from them into the warehouse. All well-holes should be built up solid from bottom to top.

Considering the great experience that has been gained from the numerous conflagrations on a large scale, both at home and abroad, we ought to be able by this time to construct buildings in such a manner that no fire can destroy them; or, at least, in which the fire can be easily confined to the single apartment in which it commences. Much has been said about having a good water supply, with hydrants all over the premises, and watchmen always at hand to extinguish the first spark of fire that may be discovered; but for our own part we place little confidence in such arrangements, as it almost invariably happens that a fire breaks out when least expected, and when either the water-supply has run short, or the watchman has been called away; and, before the appliances can be made use of, the fire has got such a hold on the premises that all the engines in London cannot put it out. With ample means at command, and an endless variety of material ready to hand, an English architect of the present day ought to find no difficulty in being more than a match for that most destructive of all elements—Fire.

THE SPEED OF UNARMORED SHIPS.

From "Engineering"

The discussion upon Mr. Barnaby's paper read last week before the Institution of Naval Architects,* contained as little of permanent value as such discussions usually do contain, but one of the opinions expressed is worth a brief examination, on account of the mischievous nature of the fallacies which underlie it. Mr. Barnaby's remarks, and his critics', upon the new armored ships, we shall consider on another occasion; for the present we will deal only with the question of speed in unarmored vessels. Of these, certain representative ships, chosen because they "promise to have some degree of permanence as types," were shortly described in the paper, the general effect of the description being to show that the navy, at least as regards its unarmored ships, is at length being built upon a definite plan. From the smallest gunboats to the largest frigates the constructive department of the navy appears at last to have made up its mind what it wants, and we may hope that the hitherto incessant variation of type—which, as Mr. Scott Russell, we think, well said, "has given us a navy but not a fleet" —will now cease to affect the unarmored portion of the navy. Mr. Barnaby's paper described three classes of small craft, with 9½ to 10½ knot speed, viz., the Coquette class—gunboats of 408 tons displacement (295 tons, measured on the old system)—and two sizes of sloops, the Arab of 620 tons and Daring of 894 (720); a 13-knot

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* Printed *in extenso* in "Engineering" of last week.

corvette of moderate size and cost, the Magicienne, of 1,864 (about 1,400) tons; and some large corvettes possessing the great speed of 15 knots, and a corresponding armament.

In this summary there is surely no suggestion of deficient speed, yet speaker after speaker rose up to rebuke the Admiralty for "going back" in the matter of speed, as though every one of the ships described were not (as we believe is the fact) materially faster than any similar vessel which has preceded it. To our mind a gunboat of 295 tons, able to steam 10¾ knots at the mile (as one of the class is said to have done), is very creditable, considering that she is also an efficient sea-going vessel, heavily armed, comparatively heavily rigged, compelled to accommodate a numerous crew, and built to stand hard knocks of all kinds. The little sloops—for both the Arab and Daring are small vessels—have also a creditable speed, considering the many calls upon their limited displacement, and we may mention that great, though we believe scarcely merited, fault has been found with one of those classes on the ground that she is "all engine room." In fact, until some great development takes place in the science of marine engineering, there is no chance of getting higher speeds from vessels of this small size, unless we are content to build a class of mere steam yachts, good for privateering operations near home, but unfit to take care of themselves at more than a day's steaming from a coaling station, or to engage with success with the smallest and slowest of gunboats, in whose design fighting efficiency has been allowed due weight. If there is really no use in 10-knot ships, we must give up building anything under the corvette class, and if nothing is worth building that cannot steam 15 knots, as half the speakers at the Institution, and so many writers in the press, appear to suppose, we must erase from the "Navy List" all but the largest and most expensive vessels, and reverse every accepted tradition of maritime warfare. Fast ships of war cannot be small, and cannot be cheap. It cannot be too often repeated that the common talk about "1,000-ton ships steaming 15 knots, and each carrying one heavy gun," etc., is nonsense of the worst description, and we can only express our surprise that Sir John Hay, an admiral and a former Lord of the Admiralty, should have thought it right, in discussing the Admiralty designs, to ask whether "any young officer present, anxious for promotion and prize money," would rather command one of the 10-knot sloops, or a "hired mercantile steamer, armed with a 64-pounder gun, and steaming 14 knots." Does Sir John Hay really suppose that mercantile steamers, small enough (*i. e.*, cheap enough) for such service, capable of steaming 14 knots, and fit to keep the sea, have any existence at all? Or does he think it would pay to charter a fleet of Sarmatians (or, say, all the Cunarders) in order to enable his young friends to make prize money? If so (and he will hardly otherwise get the speed he wants) the "hired mercantile steamers," being amply big enough, may just as well carry a dozen guns as one, and will thus appear in their true character, namely, as very imperfect, and not at all cheap copies of the Volage and Bacchante 15-knot classes in the navy—to which costly vessels we ought therefore to devote almost our whole attention. This is what all these high-speed arguments come to, little as their authors intend it, namely, let us build nothing but ships whose cost, compared with that of the largest 10-knot sloop, is nearly as 5 to 1.

Even when thus put, the argument may be defensible, but we do not think it will commend itself widely It is true, of course, that a fast war steamer will always be able to destroy or capture a small one, provided she is more heavily armed. If the armaments are equal, we see no conclusive reason why the battle should so end, simply because we do not believe in actions fought at high speeds; but as it is part of our case that the fast ship, if a war ship at all, must be larger than the other, we allow that she will have, or ought to have, greater offensive power, and thus be likely to win. This confession of the inferiority of slow ships, involves only the truism that big ships can thrash little ones, which is not a new discovery. But steam, we admit, has given it a new force. In the old days little ships could, as a rule, escape big ones. They carried more canvas in proportion to size, and though unable to fight, could run away. But with steam, size nearly always means speed; hence a little ship, once sighted by a big one, must strike to her. For this reason, we have always objected to small ironclads, as being much too costly for ships so likely to change hands, and we must allow the same objection to have weight against small ships of any kind. Are we then to condemn the 10-knot classes?

The answer lies in the fact that men-of-war have a great deal to do besides fighting larger vessels. Our navy includes, and is obliged to include, a vast number of small ships, performing duties in peace and war, which it would be sheer waste of power to set large vessels to carry out, and which, in many cases, large vessels could not carry out at all. The process of "exhibiting the British flag," from which the British merchant appears to derive so much comfort, can be just as well done by the Arab as by the Inconstant, and Chinese pirates can be exterminated better by the Coquette than by either. The 10-knot ships are fast enough to catch merchant-men (all but the higher class of steamers), and though extemporized privateers of the Alabama kind are likely to be larger, and to command more speed, the heavy armament of the Arab and Daring, and the man-to-man superiority which the crew of a British man-of-war may be expected to show over the scratch complement of a privateer, should at least preserve from molestation. If they cannot catch the privateer, that is no reason they should be condemned, if otherwise useful. They do not profess to be privateer catchers; that function belongs to another and special class. They have duties which they fulfil satisfactorily. They can at least drive off the enemies they are likely to encounter, and if they fall in with foes of heavier metal, their capture brings neither discredit, nor loss commensurate with the good they may have done in their lifetime, upon the British flag. For these reasons we think the condemnation passed upon the 10-knot small craft is altogether mistaken, and if it is made clear that no position is claimed for them as fighting ships, that they are only held to be useful for a limited but essential service, just as despatch vessels are useful, or tugs are useful, or royal yachts are useful, or any others of the special classes which figure in the Navy List, we do not think further objection is likely to be taken to them. It was not the least merit of Mr. Barnaby's paper that it clearly laid down—we believe for the first time—this division between the gunboats and small sloops and the genuine fighting ships; but the few words in which this was done appeared to have been forgotten when the discussion took place.

The lowest class of genuine fighting ship, which is described in the paper, is represented by the Magicienne, which differs but slightly from previous vessels. Her measured-mile speed is 13 knots, which, with an armament proportioned to her size, is reckoned sufficient to make her an effective convoy, and a scourge to all privateers. In this opinion we entirely concur. No extemporized privateer will be able to escape the Magicienne, nor to stand before her. Privateers of more than 13 knots we have already implied our disbelief in, unless in exceptional localities, near the enemy's ports, where very light steamers can operate, and any such, if able to escape the Magicienne, will certainly not be in a position to attack her. At the same time we agree that 13 knots, though sufficient, is the minimum speed for this important class, and we would deprecate the creation of any intermediate type between the cheap 10-knot classes, whose capture is of small importance, and the 13-knot privateer catcher, and general protector of commerce.

The Magicienne must strike, of course, without firing a gun, to the 15-knot Bacchante, which is twice as large. To abolish the Magicienne class for this reason and substitute Bacchantes, would be impossible, for the Bacchante costs more than twice as much as the Magicienne. The class of privateer catchers must be numerous, and no nation could afford a sufficient supply of Bacchantes. These must always be few, and the Magiciennes will have a good chance of not falling in with them. It is our business, of course, to see that we have more than other people, so that when a hostile Bacchante selects a cruising ground, we may have another, or something better, to send against her. It is, no doubt, only by superiority in these costly 15-knot ships that we can keep the ultimate control of the sea, and so far the advocates of high speeds are right. But in the scheme of duties just sketched there is ample occupation for slower vessels; in fact, the 15-knot ships are required but in very small numbers—numbers which will be regulated mainly by the enemy's force of vessels stronger than our Magicienne. Happily, in this class we are not likely to come short. The Active, Volage, Rover, Bacchante, Boadicea, and Euryalus, backed by the magnificent Raleigh, Inconstant, and Shah, leave us little cause to dread rivalry in the matter of high-speed cruisers. Besides, this is a class which every one commends, and which the Admiralty lacks no inducement to build; while its construction and management require a skill in which English dockyards and English officers need not fear to be surpassed. We have referred here to the Bacchante rather than to the Rover, which seems to us a less desirable type. The Rover, of 3,450 tons displacement, has an open gun-deck, and 64-pounder guns. The Bacchante, 500 tons larger, has a covered battery and 118-pounder guns, and the additional size (representing 10 per cent. additional cost) appears well applied. What is wanted is incontestable superiority to the Magicienne, and to everything like her. The announcement that "wooden ribs are finally doomed" we receive with hearty satisfaction. There are many reasons which account for the preference still given to wooden skins in the smaller men-of-war, and though the composite system of construction does not seem latterly to have found great favor in private yards, there is every reason to think that it will answer well in the dockyards. It has now had, in fact, some years' trial in men-of-war, and with satisfactory results. The following Table gives the leading particulars of the principal vessels mentioned by Mr. Barnaby, so far as they are described in his paper:

VESSELS.	Displacement.	Tonnage (Old System).	Speed.	Guns.	Proportionate Cost.	Number of Crew.	Construction.
	tons.		knots.				
Coquette class.	408	295	9½ to 10	2 64-pr 2 20-pr	1	60	Composite coppered. Guns on upper deck.
Arab " .	620	....	10 to 10½	1 118-pr 2 64-pr	1.9	90	
Daring " .	894	727	10 to 10½	2 118-pr. 2 64-pr.	2.25	120	
Magicienne....	1864	about 1400	13	14 64-pr.	5.4	220	
Rover.......	3451	....	15	2 118-pr 16 64-pr.	10	320	Iron, zinc sheathed. Guns on upperdeck. Is a ram.
Bacchante.....	3932	2679	15	14 118-pr.	11	...	Iron, zinc sheathed. Guns covered. Is a ram.

THE ATTRACTIONS OF MAGNETS AND ELECTRIC CONDUCTORS.

BY GEORGE GORE, F. R. S.

From "The Telegraphic Journal."

Being desirous of ascertaining whether, in the case of two parallel wires conveying electric currents, the attractions and repulsions were between the currents themselves or the substances conveying them, and believing this question had not been previously settled, I made the following experiment:—

I passed a powerful voltaic current through the thick copper wire of a large electro-magnet, and then divided it equally between two vertical pieces of thin platinum wire of equal diameter and length (about 6 or 7 centimetres), so as to make them equally white-hot, the wires being attached to two horizontal cross wires of copper.

On approaching the two vertical wires symmetrically towards the vertical face of one pole of the horizontally placed magnet, and at equal distances from it, so that the two downward currents in them might be equally acted upon by the downward and upward portions respectively of the currents which circulated round the magnet-pole, the one was strongly bent towards and the other from the pole, as was, of course, expected; but not the least sign of alteration of relative temperature of the two wires could be perceived, thereby proving that even a small proportion of the current was repulsed from the repelled wire, or drawn into the attracted one, as would have occurred had the attraction and repulsion taken place, even to a moderate degree, between the currents themselves; and I therefore conclude that the attractions and repulsions of electric conductors are not exerted between the currents themselves, but between the substances conveying them.

Some important consequences appear to flow from this conclusion, especially when it is considered in connection with Ampére's theory of magnetism, and with the molecular changes produced in bodies generally by electric currents and by magnetism.

As every molecular disturbance produces an electric alternation in bodies, so, conversely, the discoveries of numerous investigators have shown that every electric current passing near or through a substance produces a molecular change, which is rendered manifest in all metals, liquid conductors, and even in the voltaic arc, by the development of sounds, especially if the substances are under the influence of two currents at right angles to each other. In iron it is conspicuously shown also by electro-torsion, a phenomenon I have found and recently made known in a paper read before the Royal Society.

Numerous facts also support the conclusion that the molecular changes referred to last as long as the current. De la Rive has shown that a rod of iron, either transmitting or encircled by an electric current, emits, as long as the current lasts, a different sound when struck, and we know it also exhibits magnetism. The peculiar optical properties of glass and other bodies, with regard to polarized light, discovered by Faraday, also continue as long as the current. A rod of iron also remains twisted as long as it transmits and is encircled by electric currents; and in steel and iron the molecular change (like magnetism) partly remains after the currents cease, and enables the bar to remain twisted.

That the peculiar molecular structure produced in bodies generally by the action of electric currents also possesses a definite direction with regard to that of the current, is shown by the rigidly definite direction of action of magnetized glass and many other transparent bodies upon polarized light; also by the difference of conductivity for heat and for electricity in a plate of iron parallel or transverse to electric currents; by the stratified character of electric discharges in rarefied gases, and the action of electric currents upon it; and especially by the phenomenon of electro-torsion. In the latter example an upward current produces a reverse direction of twist to a downward one, and a right-handed current develops an opposite torsion to a left-handed one; and the two latter are each internally different from the former. As each of these four torsions is an outward manifestation of the collective result of internal molecular disturbance, and possesses different properties, these four cases prove the existence of four distinct molecular movements and four corresponding directions of structure; and the phenomena altogether are of the most rigidly definite character.

As an electric current imparts a definite direction of molecular structure to bodies, and as the attractions and repulsions of electric wires are between the wires themselves, and not between the currents, repulsion instead of attraction must be due to difference of direction of structure produced by difference of direction of the currents.

Although the Amperean theory has rendered immense service to magnetic science, and agrees admirably with all the phenomena of electro-magnetic attraction, repulsion, and motion, it is in some respects defective; it assumes that magnetism is due to innumerable little electric currents continually circulating in one uniform direction round the molecules of the iron; but there is no known instance of electric currents being maintained without the consumption of power, and in magnets there is no source of power; electric currents also generate heat, but a magnet is not a heated body.

If, however, we substitute the view that the phenomena of attraction and repulsion of magnets are due, not to continuously circulating electric currents, but (as in electric wires) to definite directions of molecular structure, such as is shown by the phenomena of electro-torsion to really exist in them, the theory becomes more perfect. It would also agree with the fact that iron and steel have the power of retaining both magnetism and the electro-torsional state after the currents or other causes producing them have ceased.

According to this view, a magnet, like a spring, is not a source of power, but only an arrangement for storing it up, the power being retained by some internal disposition of its particles acting like a "ratchet," and termed "coercive power." The fact that a magnet becomes warm when its variations of magnetism are great and rapidly repeated, does not contradict this view, because we know it has then, like any other conductor of electricity, electric currents induced in it, and these develop heat by conduction-resistance.

According also to this view, any method which will produce the requisite direction of structure in a body will impart to it the capacity of being acted upon by a magnet; and any substance, ferruginous or not, which possesses that structure has that capacity; and in accordance with this we find that a crystal of cyanite (a silicate of alumina) possesses the property, whilst freely suspended, of pointing north and south by the directive influence of terrestrial magnetism, and one of stannite (oxide of tin) points east and west under the same conditions.

THE PRESERVATION OF TIMBER.

From "The English Mechanic and World of Science."

Some time back (p. 1, Vol. XV.) we gave a brief account of the various processes which had been tried, with more or less success, for the preservation of wood. Many of these required that the timber should be thoroughly dry before being treated with the preservation solutions, but the numerous experiments made in the endeavor to accomplish this, proved conclusively that even when successful, the expense was so great that wood so preserved was likely to be employed only under exceptional circumstances. Soaking timber in antiseptic solutions has been tried and found fairly successful, but in some cases even this simple process has been found too costly for the advantages it confers, Thus the creasoting of railway-sleepers has been given up by many of the companies, because the extra endurance of the wood is not equivalent to the cost of the preservative process; and in other processes where the result, so far as lengthening the life of the timber is concerned, is as satisfactory, the value of the chemicals and the time required for their operation prohibit the widely-extended use of timber so prepared. The best results hitherto have been obtained by the use of chloride of zinc, creasote, corrosive sublimate, or sulphate of copper, either of which is found to impart an antiseptic property which endures for a longer or shorter time. These substances are, however, used singly, the wood being either simply soaked in them with or without the application of heat, or impregnated with them by means of pressure. Of late years attention has been turned to the production of an insoluble chemical salt in the pores of the wood by first saturating the log with a solution of one salt and then repeating the process with another, the object being to fill the pores with an insoluble substance by means of the well-known chemical action of interchange. Thus, wood soaked in a solution of phosphate of soda, and afterwards in one of chloride of barium, was found to resist the action of moisture so well, that after twelve months' exposure to conditions calculated to insure rapid decay, it was found perfectly unchanged; but the cost of the chemicals prevents the adoption of this process to any extent. The application of soda, soap, and sulphate of copper, has been found to act as an excellent preservative; wood and timber soaked in green vitriol and afterwards in a solution of soluble glass, has also been found fairly preserved. Still, so far as we know, nothing has been discovered giving superior results to those obtained by the use of phosphate of soda and chloride of barium.

Two patents have, however, recently been taken out for methods of preserving wood, which, if they do not accomplish all that is desired, may possibly lead to the invention of processes that will. Thus Mr. W. Leech takes 1 lb. of arsenious acid and dissolves it in 4 gals. of water; to this he adds 1 lb. of carbonate of soda, stirring the mixture till it is thoroughly dissolved. In a separate vessel he makes a solution of 16 lbs. of sulphate of copper in 16 gals. of water, mixes the two solutions together, and places them in a wood or a lead-lined vat. The timber is placed in this bath, and the solution heated by means of steam to the boiling point. A few hours' soaking is said to be sufficient, but when heat is not applied the wood must remain for at least two or three days. These solutions are applicable to wood that is already in permanent position, as telegraph poles, fences, and gates.

In these and similar cases one solution should be painted on and allowed to dry before the other is applied. When possible they should be laid on hot.

Mr. J. C. Mewburn patents a much simpler and less costly process, which, so far as oak is concerned, consists simply in boiling the wood in a solution of gallo-tannic acid, the proportions of the respective ingredients being apparently immaterial. The result is the formation of an insoluble substance in the pores of the wood. One solution only is necessary for oak, on account of the tannin naturally present in that wood, the endurance of which in moist situations is proverbial. A consideration of this fact led a M. Hatzfeld, of Nancy, to try the effect of impregnating timber with tannin, and afterwards with acetate of iron, a process which is both cheap and useful, and which is at present being tested by a telegraph company in that part of France. For many purposes sulphate of copper is an excellent preservative, but this salt is said to be readily dissolved out where the wood is exposed to rain. The direction, however, in which experimenters should look for the discovery of the simplest and best process, is that indicated by the patented inventions above described. The chemicals must be cheap, and the desired effect must be produced in the simplest way—*i.e.*, soaking, for even when the process takes a month, simple soaking will probably, in most cases, be cheaper than boiling for 24 hours.

THE EFFECTS OF UNEQUAL HEAT ON THE COMPASSES OF IRON VESSELS.*

From "The Nautical Magazine."

The paper on this subject, published in the "Nautical Magazine" for September last, has, we are glad to say, evoked still further discussion, and some of the best authorities on this matter have stated their objections to the statements and speculations made by our contributor, in a manner at once fair and courteous; but, as a serious implication is made against us of unsettling opinions by attacking well-established facts, upon which sailors may rely in the navigation of their vessels, we must now assert that, primarily, the inquiry was put forward in these pages, in order that what seemed a doubtful point might have careful thought turned upon it by men of practical scientific experience; and, if there were any truth in the supposition put forward, that it might receive practical investigation and accurate demonstration. We have been gratified to publish letters on the subject, written to the "Shipping Gazette" by Captain Evans and Mr. W. Rundell, and in every way desire complete ventilation of the views broached by our contributor; throughout, our sole object and desire having been to benefit the navigation. But we continue to think that our contributor's views are not yet found to be worthless or harmful, and we consider that if there is any truth in the supposition put forward in these pages, that the interests of the seaman will be well served if it can be clearly demonstrated; and if, on the other hand, the hypothesis has no foundation of actual fact, the sailor will again be benefited by the laying of the spectre raised by us, while Captain Evans and Mr. Rundell will be confirmed and strengthened in their well-earned authority on matters of compass deviation.

The following is Mr. Rundell's last letter to the "Shipping Gazette," and we cordially reciprocate the spirit in which he speaks of us in the last paragraph of his letter:—

"*To the Editor of the Shipping and Mercantile Gazette.*

"SIR, – In my letter of the 3d Oct., under the above heading, I pointed out that the cases quoted in the 'Nautical Magazine' as examples of deviation of the compass, arising from unequal heat in iron ships, are vague and incomplete; also that these cases, admitting their reality, and that they are correctly reported, may possibly be quite explicable by ordinary mechanical causes. It will be remembered that the examples are—(1.) A difference in the deviation as observed in the morning and in the evening in a steamer while going up the Red Sea, supposed to be due to the heat, from the sun acting on one side of the vessel in the morning, and on the opposite side in the evening. (2.) A difference of 10 deg. of deviation, in one hour, in a steamer bound from Liverpool to New York, when between Georges and Nantucket, after passing through alternate bands of warm and

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* See "Van Nostrand's Magazine," Vol. IX., p. 433.

cold water. (3.) A deviation of 10 deg. in a steamer while in port, the sun at the time shining on side of the vessel. These are the facts, and they have now to be viewed in the light afforded by the following quotations, which the writer of the article makes from 'Bakewell's Electricity.' page 229:—'All that is necessary for the development of thermo-electricity is, to heat any metallic body irregularly at its extremities . . . . The quantity of electricity excited is, to a certain point, proportionate to the different degrees of temperature communicated to different parts of the same metallic bar, and does not depend on the absolute heat. Thus, the application of ice will produce an electric current, as well as the application of heat; and by applying ice to one corner, and (heat) the flame of a spirit-lamp to the other, at the same time, the effect is greatly increased.' The writer in the 'Nautical Magazine' does not at once apply these obscure sentences to explain the three examples, but asks, 'Is it not possible that we have in this a clue to the secret for which we are searching, and is it not possible that the fact of the City of Washington being out of her course was owing to the action of unequal heat on her hull, and the consequent effect on her compasses?' This would have been a reasonable sequence if he had already shown how the quotation explained the three examples; but, without first giving the application and the necessary explanation, he merely makes an appeal to our imagination. This faculty is, no doubt, useful in scientific matters, but we may fairly quote here, in reference to the imagination, the very proper remarks on the compass which occur in another part of the paper in question:—'As a useful and capable servant it may be relied on; but, if once confided in without due intelligence, and without a knowledge of the effects of outside influences on it, the good servant becomes a bad master.'

"Let us, however, without stopping to pry into the secret to which a clue is wanted, quietly examine the extract from Bakewell, and try to apply to iron vessels the remark about the heating of 'any metallic body' irregularly at its extremities. Let us try, also, to form some idea of applying cold 'to one corner,' and 'heat to the other' corner, of an iron ship, when, we are told, 'the effect is greatly increased.' What parts of the iron ship represent the extremities, and which the corners here spoken of? The bow and stern may, perhaps, fairly represent the 'extremities,' but the 'corners' will afford scope for a good deal of imagination, even when we explain that in thermo-electric experiments bars of different metals are frequently united together at the extremities in a way which makes an angle or corner; and further explains that the thermo-electric effect, when it is produced, depends very much on the difference of temperature at the opposite extremities of the bar, or, if more than one pair of bars of two metals are used, on the difference of temperature of the alternate corners where the two metals are united.

"We will not be too exacting, or put the writer of the article into a 'corner' by asking where the two metals properly arranged for producing this electrical effect are to be found in an iron ship; but we will assume that they may easily be found, and in positions in which thermo-electricity may be produced: 1. When the sun is shining on either side of the vessel. 2. By an iron ship entering or leaving spaces of warm or cold water, when, of course, the 'extremities,' for a few moments, would be 'unequally,' and, perhaps, as Bakewell also seems to require it, 'irregularly' heated; 3. By a uniform, or irregular, difference of temperature between the bottom and top sides of a ship, whether sailing in warm or cold water. Let us grant all these assumptions as necessary to the explanation of the three examples; there are yet some others which must be made, and which must not be forgotten.

"Thermo-electricity, then, to use popular language, is unlike ordinary electricity, it cannot pass through spaces of air; neither can it, like galvanic-electricity, pass through somewhat tarnished metallic surfaces; it requires what is termed good, clean, metallic contact, for rust or dirt would stop it altogether, and would break the circuit which is necessary to the production of any effect on the ordinary compass needle. Any one who has seen rivets and but straps taken from an iron ship will know that such clean metallic contact does not occur throughout an iron vessel; but we make light of all such difficulties, and many others which intervene, for the purpose of testing, in imagination, the effect of a thermo-electric current, strong enough to act at a distance of some feet, on the compass of the steamer in the Red Sea, example No. 1.

"The effect of the thermo-electric current on the magnetic needle is this. It tends to place the needle at right angles to the direction of the current, and moves the north end of the needle to the right hand when the current is passing in one direction, and to the left hand when the current passes in the opposite direction, if the needle be on the same side of the current. Now, we may suppose that the thermo-electric current in the steamer in the Red Sea, either passed round the sides of the vessel horizontally from right to left or from left to right; or that it passed across the vessel through the beams or iron deck, either from port to starboard or from starboard to port. What then would be the effect on the compass needle under these four conditions? Simply none at all! Under one set of conditions there would be no horizontal motion of the needle, and in the other the needle is already at about right angles to the direction of the current.

"I trust, however, enough has been said to show that very little foundation exists for the supposition that unequal heat in an iron vessel has an appreciable effect on the mariner's compass. But if it had, we need not seek for it alone in the comparatively trifling changes of temperature due to warm or cold currents of water, or the presence or absence of sunshine; or to thermo-electric effects, which require for their demonstration the use of a delicate galvanometer, an instrument which does for the electrician what a powerful microscope does for ordinary vision. Did the writer of the article forget the engine and boiler space, the heat of the stokehole, the tons of coal which are burning day and night in an Atlantic steamer to keep up steam? Here we have hundreds of degrees of difference of temperature instead of the few degrees which appear to have so exercised his mind. We have here a much wider field for inquiry, and possibly a more productive one, for thermo-electric currents which fail to affect the compass, and are next to impossible in the shell of an iron ship, may, under some circumstances, materially assist to destroy parts of the boilers and machinery.

"This letter, however, is not intended to discuss such questions, but to point out the weakness of the hypothesis which ascribes compass errors to unequal heat, and more particularly to point out the bad tendency of an article which must induce in seamen a state of unreasonable distrust in their compasses, and what is worse, a disinclination to try and master a branch of their profession, which seems surrounded with so many difficulties. It tends also to paralyze action in cases of emergency, by leading the navigator to suppose that in his compass he has to deal with occult and mysterious influences, which he cannot hope to understand. As Captain Evans has observed, its tendency is to take us back twenty years, to ignore altogether the labors of those who have devoted their energies to the elucidation of what was once a difficult subject, but which has now been rendered easy, and is full of interest to all who will devote only a moderate share of attention to its study. The true friend of the seaman will direct his attention to the well-ascertained facts of the science, and amongst these, when properly understood, will be found nothing to support the idea that unequal heat, magnetic storms, electrical discharges, in the atmosphere, fogs and the like, affect to any sensible degree the navigation of an iron vessel. Such articles as the one in question tend, too, as Captain Evans also very justly remarks, to place the navigation of an iron ship beyond the scope of known physical laws, and to place the navigator of the iron ship outside the responsibilities of moral law.

"This may occasionally be a convenience to the shipmaster when in trouble, and placed before a Court of Inquiry incompetent to deal with such subjects, but it takes from him at other times all the merit of skilful and successful navigation, by reducing his success to a mere matter of chance, to the result of a balance of 'unknown,' 'unsuspected,' 'frequent,' 'temporary,' and 'ever-varying,' but happily, generally, self-compensating errors.

"Those parts of the article in question which refer to deviation from heeling, and others which underrate the importance of thoroughly testing the competence of the professional compass adjuster, also call for remonstrance; but there is no space for it at the end of this long letter. I must, however, beg permission to add a few lines, to say that I hope the object of my remarks will not be misunderstood by the editor of the 'Nautical Magazine.' As a constant reader and admirer of that very useful periodical, my desire is to aid in making it a discreet, as well as a warm friend of the seaman. We are in many respects in the 'same boat' as the 'Shipping and Mercantile Gazette,' and I should be very sorry to have it supposed that my strong objection to the tendency of a particular article, or that your insertion of my adverse remarks, are to be taken as a sign that the general merits of the 'Nautical Magazine' are undervalued by me."

DOMES OF STONE AND BRICK.

From "The Building News."

The attention of our readers was recently called by us to the construction of iron domes for covering very large areas without the necessity of ties or buttresses, and some of the advantages, as well as disadvantages, attending the use of this material were pointed out. We now propose to take into consideration the construction of domes with more permanent and enduring materials, such as stone, bricks, or terra-cotta, and concrete or artificial stone. For such buildings as are intended to last for ages without requiring any heavy expense for repairs, the use of iron as a material for construction is scarcely admissible, unless some means can be devised of protecting it from the corrosive action of moist air. Iron has also the defect of being very sensitive to variations of temperature, expanding with irresistible force as that increases, and contracting again as it diminishes, so that a very large roof of iron may be said to be in constant motion from the changes of temperature to which it is exposed during the whole twenty-four hours of each day. Moreover, when a hot sun is shining on a dome of iron it will be heated much more on one side than on the other, which will tend to produce a distortion of its figure, and an unequal strain upon various parts; and as this goes on constantly for many years, the strength of the substructure must be gradually but surely diminished. Hence we see that, although such structures are admirably adapted for temporary purposes, and those in which rapidity of erection is an essential point, yet for buildings intended to last for centuries the only material to be relied upon is either stone or brick.

Domical vaulting has been but little used in Great Britain, and no English architect since the time of Wren, appears to have attempted to erect a large dome of stone or brick. We must, therefore, look to other countries for the finest examples of this mode of construction, and these are very numerous in Italy, Turkey, and India. Very few domes appear to have been built with voussoirs of masonry, either brick, terra-cotta, or rubble stone being the material of construction. The external dome of the Pantheon at Paris is of masonry, and of very light construction, but the weight of the lantern is chiefly supported by an inner brick dome of conical form.

When we examine the most celebrated domes that have been built in various countries, either in ancient or modern times, we find two distinctive features in their design: first, where the dome is used simply as a covering, as that over the Church of Santa Sophia at Constantinople, and has no load to carry; secondly, where the dome is employed as the chief external feature of the building, and is loaded with a heavy lantern of masonry, as is the case with those of S. Peter's at Rome, Santa Maria at Florence, and S. Paul's in London. There are also two distinct modes of construction employed in these domes; one in which the main portion consists of a number of curved ribs rising from the drum or supporting wall and gradually tapering towards the summit, with horizontal rings between them, so that the whole surface is divided into a number of panels the filling-in of which is much lighter and thinner than the main ribs themselves. The other mode is to build the whole dome with a smooth surface inside and out, and of uniform thickness in each horizontal course, so as to be perfectly homogeneous throughout and of equal strength in every part.

The former of these systems is the one that has prevailed in most of the great domes of ancient or modern times, although the want of homogeneity which it entails has generally led to serious settlements from the unequal pressure which is thrown upon different parts of the substructure. The dome of the Pantheon at Rome (142 ft. diameter) is built in this manner, with ribs and rings dividing the internal surface into deeply recessed panels; the enormous thickness, however, which has been given to every part of this vault, and its supporting walls, render it perfectly safe from all risk of settlements, and, indeed, the thickness at the thinnest part of the panels is much more than sufficient to secure the dome, even if all the extra thickness of the ribs were taken away. A similar system was employed in other old Roman domes, as that of the temple of Minerva Medica (81 ft. diameter), where the ribs were standing by themselves long after the filling-in to the panels had been destroyed.

Coming to more recent times, we find the dome of Florence (138 ft. diameter) built on the same system; the plan is an octagon, and there is a vertical rib at each of the sight angles with an intermediate rib in the middle of each side. There are no horizontal rings, but the filling-in between is of such great thickness as to obviate the necessity for them. The only external tie which has been used to prevent horizontal thrust upon the drum is round the bottom of the dome. There would, however, be but little horizontal thrust in a dome having its section, which is that of a pointed or Gothic arch, and the great thickness of its double casing renders its stability certain so long as the substructure does not yield at any point. The cupola of S. Peter's at Rome (139 ft. diameter) is built in a similar manner to that of Florence, but on a circular drum instead of an octagonal one. Several settlements occurred in this dome, but these arose from defects in the foundations and supporting piers, and not in any want of stability in the dome itself. All these domes are constructed either of brick or rubble masonry, and not of hewn stone worked into the form of voussoirs.

In the external dome of the Pantheon at Paris, which is 78 ft. external diameter, the construction is of regularly-coursed masonry, the rib and panel system being adopted. This dome is, probably, the lightest in proportion to its size that has ever been built, the thickness of the ribs being 26 in. at base and 13 in. at the summit, giving a mean thickness equal to one forty-fifth of the diameter, while the panels are only one-half that thickness. There is a stone lantern above, but the external dome has very little of its weight thrown upon it, which is chiefly borne by an inner cone of brick, as in the dome of our own S. Paul's.

The second mode of construction employed in forming a domical vault is where the whole dome is made of uniform thickness, and not divided into ribs and panels; and this appears to be the most proper, as well as strongest, mode of constructing a large dome, which may be formed either of hewn stone cut in the wedge form, or else of rings of ordinary bricks, or hollow voussoirs of terra-cotta. We have a fine example of this kind of construction in the dome of Santa Sophia at Constantinople, which is nearly a hemisphere of 110 ft. diameter, and is elevated on a circular drum. Internally, the springing of the dome is about 5 deg. above the horizontal line through the centre of the generating circle. Externally, the dome begins at a point which would make an angle of 30 deg. with the centre, and is nearly uniform in thickness above that point, being 2 ft. thick at the crown; below 30 deg. the thickness is about 5 ft. There is little doubt that such a dome, which is without any lantern or load at the summit, would be perfectly stable even if there was much less thickening out at the base, provided the supporting piers and walls did not settle unequally at any part. The great dome of the Gol Gomuz, at Beejapore (124 ft. diameter), is of uniform thickness throughout, but that thickness is so enormously great—about 10 ft.—that it can hardly be taken as a fair example of a well-constructed dome.

We will now briefly consider domes in their two distinctive features—namely, first, those which have no heavy lantern to support, and, secondly, those in which the lantern forms an important part of the design. Where the dome has only its own weight to carry, the problem of stability is a very simple one; we must first make sure that we have a solid foundation, and that our piers or walls are well constructed with regular courses of masonry, and not filled in with rubble work, by which all the weight of the superstructure will be thrown on the outer casing of ashlar, which has been the principal cause of the failure of many large cupolas. If we build our dome in ribs and panels we must also take great care that the pressure of the ribs is distributed as uniformly as possible over the whole of the points of supports so as not to produce unequal settlement. The thickness of the dome at the base should be about $\frac{1}{45}$ of the diameter if hewn stone is used in the construction, as in forming an arch. This thickness should be diminished upwards to about $\frac{1}{2}$ the thickness at the base; and if in ribs and panels, the latter may be made half the thickness of the ribs. Such a dome, constructed of masonry carefully fitted, will require no outside belt to prevent bursting or thrusting, provided the walls are of a thickness considerably greater than that of the dome, such thickness depending upon the height they are carried up from the ground.

It was proposed by Rondelet, at the end of the last century, to put a domical roof of hemispherical form over the Halle au Blé (Cornmarket), at Paris, to be built of hewn stone, with a diameter of 130 ft., the thickness at the springing to be 28 in., diminishing gradually to 14 in. at the summit. An eye was to be formed in the centre of the dome 25 ft. in diameter, and a light iron lantern weighing 4 or 5 tons, erected over it. The average thickness would be $\frac{1}{70}$ of the diameter. In this case the weight of the lantern would have been considerably less than that of the portion of the dome cut out to form the eye, and as that is the part which presses most heavily on the lower portion of the dome, by cutting it out we reduce very much the risk of outward thrust, and no external belts will be necessary. Unfortunately, Rondelet's design was not carried out, but one of timber erected instead.

Most of the remarkable domes have, however, to carry the weight of a stone lantern, vastly heavier than the masonry omitted to form the central eye. Such a superstructure, placed where it produces its utmost possible effect, would inevitably burst out such thin domes as we have just noticed, unless they were very strongly tied in with belts of iron surrounding the lower parts of the vault. Hence we see the reason why those of St. Peter's, at Rome, and Santa Maria, at Florence, have such great thickness given to them as about $\frac{1}{20}$ of their diameter. It is almost impossible, also, to build large domes, having such a thickness, of solid masonry, and brick has, therefore, been invariably used in their construction. Brick has, however, the defect of being of variable strength, and requiring a much larger quantity of mortar or cement than masonry does; consequently, the risk of settlements is vastly increased, and the necessity arises for increasing unduly the thickness of the dome, and of also removing all risk of its bursting asunder by putting iron belts around it. In spherical domes the weakest part is about 20 deg. above the springing, and in such a dome as that at Florence it is about 13 deg. above the springing line; so that the greatest effect of a belt is obtained by placing it round the dome at that point where the tendency to bursting is greatest. If such domes as those of Rome and Florence were to be built of masonry they would be quite stable if only half their present thickness, and would carry their heavy lanterns without thrusting out the drum or bursting at the haunches. The dome of St. Paul's, in London, has a lantern of enormous weight to support; but in this case the real dome is concealed from view both externally and internally, the lantern being carried on a brick cone, 18 in. thick, which inclines to the horizontal at an angle of 66 deg. The inner dome which is seen from below is also of brick, 18 in. thick, built in form of a hemisphere with a large eye cut out of the centre, and having no load whatever to support. The external dome, which forms the grand feature of the building, is a framework of timber supported upon the internal cone before mentioned. The conical form of vaulting is, no doubt, far stronger than any other, and next to it in strength and stability is the paraboloid, whose vertical section is a parabola, having its axis vertical; then comes the dome having a pointed Gothic arch for its section, the strength of which depends on the pitch of the arch. All these forms of dome will bear the load of a lantern better than the hemispherical one, and will have less tendency to burst. Segmental domes, as they are called, whose section is a segment of a circle, in which the springing is not more than 52 deg. from the vertex, have no tendency to burst, but rather to fall inwards, which must be resisted by a belt at the springing, or by having the supporting walls of a sufficient strength to resist the outward thrust thereby produced.

In building a brick dome of large size to carry a heavy lantern, iron belts should be introduced in all the lower portion, beginning at a little distance above the weakest part or point of rupture before mentioned; this can best be done by introducing hoop-iron into the mass of the brickwork, or if hollow bricks or terra-cotta voussoirs were used, the hooping might be threaded through the bricks and securely fastened at the ends. By this means a greater degree of homogeneity is imparted to the structure than by placing iron belts round the outside. Domes built of solid masonry, in which each stone is a "through," can be prevented from bursting by having dovetailed iron dowels let in at each abutting joint, and run with lead, so as to form one continuous chain all round, which no pressure from above short of crushing the material could possibly rend asunder.

Many persons make the mistake of regarding a dome as an arch, but in reality the two have but little in common. A large stone arch requires a strong scaffolding or centring to support the stones in the upper part until the key-stone is fixed; whereas, as soon as any one horizontal course of a dome is completed, it requires no further support, and we only need to keep the stones or bricks of each course in their places until the whole ring is filled in; so that no centring is required for dome building, a travelling pole having a cap at the outer end being sufficient to keep the courses in place until the cement is set on the ring finished; and even this can be dispensed with if we notch or dowel one course on the top of that below it. The thrust also of a dome is much less than that arising from an arch of equal diameter, and can be counteracted with greater readiness in the way we have seen. Although, however, the thrust of a dome is much less than that of an arch, yet analysis shows that whereas that of an arch increases as the square, or second power of the span, the thrust of a dome increases as the cube, or third power, of the diameter; this fact must be borne in mind in designing the supports of very large domes, which must be made thicker in like proportion.

There is another kind of material that we have not yet noticed, but which might be advantageously used for the construction of domes, namely, concrete, or artificial stone. This material has been extensively employed in the construction of walls, arches, and vaults, and, when properly treated, it appears to possess great homogeneity and power of resisting strains. There are two ways in which such material can be employed in dome building—one in which it is first cast into blocks of a suitable size and shape, and then built into its place in the way that stone would be used; the other mode is, form a kind of box, in the exact position in which the dome is to stand, and fill-in with the concrete in a loose state, the box being shifted to another part as the material sets and hardens. With this material it is advisable to permeate the mass with plenty of hoop iron, so as to give it tensile, as well as compressive strength, and prevent unequal settlements occurring and producing fractures.

With the great experience which we possess in modern times of the strongest as well as weakest forms of domical construction, and the knowledge that has been acquired of the strength of materials, we ought to be able to erect domes of stone, brick, or other durable material, which shall completely eclipse those of ancient times, both in magnitude and elegance of design.

Those who wish to make themselves acquainted with the mathematical theory of dome vaulting will find the subject fully and ably discussed in a paper by Mr. E. W. Tarn, read before the Royal Society in 1866, published in the "Proceedings" of that year, and afterwards in the "Civil Engineers and Architects' Journal" for March, 1868; also in an elaborate and exhaustive paper by Mr. E. B. Denison, read before the Institute of Architects, in February, 1871. By carefully comparing the theories with practical knowledge of construction, the architect is enabled to judge how he can best use the materials and other means at his disposal so as to produce an edifice combining stability of structure with elegance of design.

ASPHALT AND WOOD PAVEMENTS.

From "The Architect."

Mr. William Haywood, the City Engineer, has presented another report on asphalt and wood paving, with the object of showing the relative advantages of both. Wood pavement was laid down in the Old Bailey in 1839, and then in other streets, but none of them lasted more than seven years. The streets were then not cleansed as well as now, nor was the mode of preserving the surface well understood. Experience in pavements was almost entirely confined to granite of a superior quality to that which now comes to London, and of stones more than double the size of those now generally used; and as the duration of some of the wood pavements was so small, and their cost much larger than granite, a prejudice appears to have arisen against wood, and the pavements, as they wore out, were for the most part replaced with granite.

Wood was, however, retained in Mincing Lane, Gracechurch Street, Cornhill, Lombard Street, Bartholomew Lane, Lothbury, and in part of the Old Bailey, until within the last three years, when, with the exception of that in Bartholomew Lane, it was replaced with asphalt.

At the end of 1873 five descriptions of wood paving were in existence in the City, viz., Carey's Improved Wood, Ligno-Mineral, Mowlem's, and Stone's. Their total length was 1,059 yards, and the superficial area 12,238 yards.

The first asphalt pavement was laid in Threadneedle street in May, 1869, and was formed of the compressed asphalt of the Val de Travers Company. Cheapside and the Poultry were laid with similar asphalt in the autumn of 1870, and many thoroughfares have since then been paved with it and asphalts of other kinds.

At the end of the year there were six descriptions of asphalt, viz., Val de Travers (compressed); Val de Travers (mastic); Limmer (mastic); Barnett (mastic); Société Française (compressed), and the Montrotier (compressed). The total length was 7,484 yards, and the area 60,802 yards.

Mr. Haywood says that no two pavements, whether of asphalt or wood, are exactly similar in their qualities, nor will they be of the same durability or cost. It may be necessary specially to refer to some, although, for the most part, the remarks in the report will be applicable to asphalt and wood generally. Nevertheless, as it is needful to make direct comparison upon some points, the Compressed Asphalt Pavement of the Val de Travers Company and the Improved Wood Pavement have been selected as being the best examples of their several kinds, and of which there are the largest quantities now laid in the City, and elsewhere in the metropolis. The following is a brief description of them:—

The Compressed Asphalt Pavement of the Val de Travers Company is formed of a natural material, procured from a mine in Switzerland; it is laid upon a bed of cement concrete, in a state of heated powder, and so as to be, when compressed, from 2 to 2½ in. in thickness, according to the traffic of the street.

The Improved Wood Pavement is formed of fir blocks, 3½ in. wide, 10 in. long, and 6 in. deep, laid upon a foundation of two thicknesses of fir planks, well pitched and nailed together; the blocks are placed together at their short ends, but on their longer sides are joints, running from side to side of the street, ¾ in. wide, the lines of joint being kept by fillets nailed to the planks; the joints are filled up with clean, small pebbles rammed in, and then run with a composition, formed of pitch, tar, or other bituminous substances.

With regard to asphalt, Mr. Haywood says, that although there is much larger experience in its use than there was in 1871, when he reported upon the comparative merits of asphalt and granite pavements, he sees no reason upon most points materially to alter the views and opinions then expressed, and much then said has been repeated in the present Report.

The qualities of the pavement considered in the Report are their (1) convenience, (2) cleansing, (3) construction and repair, (4) safety, (5) durability and cost.

Convenience.—The principal, if not the sole, object of employing either asphalt or wood for pavements is to diminish the noise of the traffic. Asphalt is less noisy than granite; for, being smooth and without joints, wheels run almost as easily over it as on a tramway, and the noise is caused almost entirely from the clatter of the horses' feet. Wood is less noisy than asphalt, the horses' feet making no clatter upon it; in fact, wood makes the most quiet of all known pavements. Asphalt cannot be suffered to get materially out of repair, for if it does it is speedily knocked to pieces; therefore, the quietness and the comfort it affords will be at all times nearly the same. Wood pavements, being composed of blocks of different sizes and jointed in different manners, are in the course of time worn into inequalities, and carriages are then more jolted and there is more noise than when the pavements are new; but this is principally experienced by those inside the carriages.

The extent to which this irregularity of surface takes place depends much upon the care taken in its maintenance, but also upon the nature of the pavements; those formed of large blocks with wide joints wear more unevenly than those of small blocks with close joints. The owners contend that their Improved Wood Pavement, having no short joints and the blocks reposing upon a slightly elastic foundation, will not wear unevenly, and probably it will wear more evenly and last longer than any other wood pavement yet laid, but it certainly will wear somewhat round in the direction of the traffic. Pedestrians, where the carriage traffic admits of it, walk largely upon asphalt, but they do not walk so much upon the wood.

Asphalt being impervious, water runs off it quickly or is soon evaporated. Dirt lingers in the joints of wood pavements, and is worked out by the traffic, making the surface dirty for some time after rain. The relative advantages of the two pavements in this respect depend, however, largely upon the care taken in cleansing. Wood absorbs moisture, and is very frequently damp when asphalt is dry; but if it be reasonably clean, the dampness does not affect the safety or comfort of the traffic. When dry weather ensues after rain, dust clings to the wood, and there is no dust for some time.

It has been said that wood pavements at times smell offensively, and may be unhealthy; but although some City streets have been paved with wood for thirty years, no complaints have been made to the Commission, and the inhabitants at all times have not only expressed great anxiety lest the wood should be replaced by other material, but have subscribed towards the cost of its renewal. In the northern towns of Europe wood pavement is much used. In America and Canada many of the largest cities are paved almost entirely with wood, and it is not there believed to be unhealthy. In confined places, and under some conditions, wood might be considered unhealthy.

Are wood pavements likely to be the means of spreading a conflagration? It was found by experiments made by Mr. Haywood, in conjunction with Captain Shaw, that asphalt, subjected to a more severe test than it would be in an ordinary fire, would not aid in spreading a conflagration, and there is no reason to suppose that wood would be more likely to do so, laid, as it is, under conditions rendering surface ignition improbable. At Chicago the foot pavements were, in many cases, formed of planks laid on wooden joists, the whole structure being 1 or 2 ft. above the carriage-way, and subject to the action of the fire on both sides; but it is doubtful whether the fire was materially, if at all, increased by those footway pavements.

Cleansing.—Both asphalt and wood should be kept very clean for safety; but great cleanliness is more important to asphalt than it is to wood. Asphalt can be kept cleaner than any other pavement, for, being non-absorbent and without joints, the broom, the scraper, the shovel, or water, can be applied to it most effectively. Wood pavements are more difficult to clean on account of the joints and the absorbent nature of the material. Experiments made in 1867 and 1873 in washing granite and asphalt with jet and hose, showed that asphalt costs slightly less than granite; but that a higher state of cleanliness can be attained on it. It is probable that the cost of washing wood would also be more than that of asphalt. Washing is the best way of cleansing all pavements, and it is desirable that an experiment be made on wood at an early opportunity.

Construction and Repair.—Compressed asphalt, with a concrete foundation, was laid in Cheapside at the rate of 129 yards a day, and the Improved Wood Paving was laid in Ludgate Hill at the rate of 125 yards per day. Other wood and asphalt pavements can be laid as expeditiously—that is, in fine weather, for in wet weather neither the concrete foundation nor the asphalt can be laid. Wood blocks, if not requiring a concrete foundation, can be laid in most weathers, but the grouting of the joints, whether with lime or asphalt, cannot be properly done unles the weather be reasonably dry. The same remarks apply to repairs both to asphalt and wood in respect of weather.

Very small surface repairs can be made with facility in all asphalts. In compressed asphalts they can be made so neatly as not to be noticeable after a short time, but in the mastic asphalts the joints remain visible. The ease with which repairs can be made to a wood pavement depends upon its character; ordinarily they can be done with the same facility, and are executed in much the same manner as to granite.

As regards the safety of the two pavements, we noticed on January 10 the special report of Mr. Haywood on this part of the subject, so we need not now repeat what is said in the present report.

Durability and Cost.—There is not enough experience to determine the durability of asphalt. During the past three years eleven different sorts have been tried, five of which have failed; and there are others in an unsatisfactory condition, some showing unmistakable signs of decay, and the necessity for a not far distant renewal or extensive reparation. Compressed asphalts have hitherto proved themselves the most durable; those which had been the longest down were examined carefully last year, and the loss on them by wear found to be small, and they were generally in good surface condition.

More than two dozen different kinds of wood pavement have been tried in the City. The average life of wood in three streets with the largest traffic was about nine years, and in three streets with the least traffic about eleven years and a quarter. Nearly all, before they were removed, had been relaid over their entire surface, and some new wood introduced from time to time in lieu of that found too defective to relay. In New York it has been found that the average duration did not exceed five years. The general conclusions which Mr. Haywood draws are:—

(1.) *As regards convenience.*—That Asphalt is the smoothest, driest, cleanest, most pleasing to the eye, and most agreable pavement for general purposes, but Wood the most quiet.

(2.) *As regards cleansing.*—That Wood may be kept cleaner than it has hitherto been, but will be more difficult and expensive to cleanse effectually than Asphalt. That as both pavements require occasionally strewing either with sand or gravel, there is not much difference between them in that respect.

(3.) *As regards construction and repair.*—That Asphalt and Wood, taking all seasons and weathers into account, can be laid and repaired with about equal facility, but that the smallest, neatest, cleanest and most durable repairs can be made in Asphalt.

(4.) *As regards safety.*—That whether considered in reference to the distance which a horse may travel before it meets with an accident, or the nature of the accident, or the facility with which a horse can recover its footing, or the speed at which it is safe to travel, or the gradient at which the material can be laid, Wood is superior to Asphalt.

(5.) *As regards durability and cost.*—That Wood pavements, with repairs, have in London had a life varying from six to nineteen years, and that with repairs an average life of about ten years may be obtained; that the durability of the Asphalts is not known, but that under the system of maintenance adopted, they may last as long as Wood; that contrasting the tenders for laying and maintaining for a term of years the two best pavements of their kinds, Wood will be the dearest.

Although the foregoing remarks apply in most cases to Asphalt and Wood pavements generally, yet they are more strictly applicable to the compressed Asphalt of the Val de Travers Company and to the Improved Wood Pavement, and where the climate and other conditions differ widely from the metropolis, different results as to safety, cost, etc., may be expected.

ON FIRE-PROOF BUILDING.*

From "The Builder."

The ordinary construction, called fire-proof, consists of brick arches carried on iron beams, which generally rest on iron columns for intermediate support, the end arches being tied by iron bars to prevent outburst of the walls; and what generally happens when a fire takes place is, that the columns become softened or split by a dash of cold water while they are very hot, or the under side of the girder—which is generally exposed to the greatest strains—is weakened by heat or split by suddenly cooling, or the tie-rods lose their tensile force; the floors fall in, the walls fall out; and the very process adopted for the preservation of the building greatly facilitates its total destruction. Of the two, a com-

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* By Mr. James H. Owen, M. A. Read at a meeting of the Architectural Association of Ireland, December 18th, 1873.

mon timber floor, well sealed underneath, would have lasted longer, thereby giving more time for salvage, and could not, at the worst, have suffered more than the pseudo-fire-proofing; but still something can and must be done to protect the ironwork, as by its means alone can the sort of structure which is required for the business be erected with the necessary stability.

In designing such a building, the architect should first ascertain the smallest area that he can be allowed to use as the unit of construction; he should subdivide by internal partition-walls as far as he will be allowed to do so; and, having thus arrived at the cubic spaces of which the intended building is to be composed, and finding that the spaces over which he has to carry his floors render it necessary to avail himself of the constructive facilities afforded by iron, he must set himself to work deliberately to contrive such a mode of using it as will protect the iron from the effects of fire. If columns are required for intermediate support, I think they might be of iron, of somewhat larger diameter than usual, and the interiors filled solidly with cement concrete, carefully packed and rammed, the idea being that the cement should form an interior column capable of sustaining the load in the event of the iron failing; or of +-shaped iron, with a coating of brick in cement; or, best of all, a simple shaft, with cap and base constructed of bricks laid in fine Portland cement, as nearly skin to skin as possible. These would be not very sightly; but that is of very slight importance when the enormous damage to be overcome is considered; but as it is not worth while to make anything uglier than it need be, I should recommend a shaft square on plan, with edges chamfered, and stopped at top and bottom. This would have the appearance of a clumsy timber post; but a series of them would not look amiss. Then, as regards the floor itself, in which I include not the surface only, but the whole mass from floor to ceiling which separates the two stories, —what we have to do is to support an area, say 15 ft. or 20 ft. square, and at the same time present to the action of fire a surface, above and beneath, which shall be absolutely uninflammable, and which shall not be subject to any alteration of dimensions or strength by the action of fire,—not be destroyed by the action of wet. I believe these objects would all be attained as nearly as possible by the construction which I have sketched, which consists of a beam of rolled iron resting on a cushion of brickwork not less than 3 in. over the finished top of the pillar. When the beam is set it should be painted and well sanded all round; then a platform or centring should be erected of the exact form of the intended under-surface of the ceiling when finished; over this tiles of any pattern that may be approved should be laid, face downwards, filling up the whole surface; the remaining space should be then filled in to the level necessary for laying the floor tiles with a concrete prepared of Portland cement, sharp silicious sand, and broken bricks and potsherds, or broken granite or sandstone, carefully excluding all calcareous stone, gravel, or sand. The upper surface should be properly levelled and floated, and a course of flooring tiles laid and grouted with cement in the ordinary way. The supports of the centring should be suffered to remain as long as possible, and it would be advisable in all cases to finish each floor complete *pari passu* with the walls, letting the cement concrete which forms the floors rest solidly for some inches in and on the outer walls.

There are, I confess, doubtful, or rather unsettled, points about this construction, viz.—1st. The proportion of the load to be supported by the iron girders, and consequently what the proportions and sectional area should be. 2d. The transverse strength of beams or slabs of cement concrete; no experiments that I have been able to find have yet been made to determine this. 3d. Whether the tiles forming the under coating would not be detached by fire or water suddenly dashed against them when hot. I would wish to say a few words on each of these points. First, as to the basis of calculation of the load to be borne, or the amount of work to be done, by the iron. It will be observed that from the nature of cement concrete it differs from a floor formed either of beams and joists or of a brick arch, inasmuch as it resembles a slab of stone; and in that it is at one and the same time, both in load and self-supporting, within moderate dimensions, we can readily conceive a square slab of concrete to be independent of support except on two sides of it. And here comes in the second doubtful point. If we had the strength of a slab of concrete stone as well known as that of a slab of granite or limestone, we should know exactly that with a certain thickness we could use it with safety for a certain projection beyond the supporting wall. To take an example: no architect would venture to fix a landing of granite projecting 4 ft 6 in. from the supporting wall, and 6 in. thick, or to cover a space 9 ft. between the walls by slabs of granite 6 in. thick; in either case it would be recognized that iron beams under the joints would have nothing to do—would be superfluous. We have not that experience as regards slabs of concrete; we do not know how far they are to be trusted; and therefore I recommend the employment of iron in conjunction.

The only experiments of which I have any knowledge which have been made in this direction are those of M. Vicat, and one made at the Great Exhibition of 1851. M. Vicat made a beam of hydraulic lime and granite sand (beam fixed at one end and loaded at the other), of the following dimensions:—

Experiment No. 7.—L 0.03 c.=.098427 ft.
D 0.025 c.=.98427 in.
B 0.04=1.5748 in.
W 32.00 kil.=.62096 cwt.
Experiment No. 8.—47.00 kil.=.92515.

Applying the general formula $W=c\frac{b\ a^2}{L}$ we find the value of c to be, in No. 7, .16 cwt., and in No. 8, .235 cwt. These results are very low as compared with the value of c for other materials; as, for instance, 3 for Riga fir, 4 for red pine, 18 for cast-iron, etc. I cannot help thinking that the exceedingly small dimensions operated on were very unfavorable for an experiment of the kind on such a material.

The experiment made at the Great Exhibition of 1851 was somewhat similar. The beam was of pure Portland cement, 14 in. long, 4 in.×4 in., and it bore 1,580 lbs. Adopting the same formula, this gives a value of 1.174 cwt. for c, or rather more than one-half the value for Riga fir. But as Portland cement loses its strength very materially by admixture with sand, we must reduce the constant very materially for this reduction; but, on the other hand, there is nothing easier or more natural than to increase the strength of the Portland beam by giving it a curved form underneath; and for the same reasons that we make a beam of iron of a parabolic form in order to collect the materials exactly in to the place where they will produce the maximum of effect, so we should give the beam of Portland cement an arch form of the same shape underneath; and it is not improbable that this expedient would make up for the loss of strength caused by adding sand and gravel to the cement—or, in other words, of using concrete in place of pure cement.

One other thing to be borne in mind is, that in all cases of using cement concrete for covering over spaces, the value of B becomes extended. In an ordinary beam we have B only a few inches, and bearing the weight of an average of 10 ft. of floor. In the Exhibition experiment the weight amounted to nearly $4\frac{1}{2}$ cwt. per ft. superficial of floor; and as the exterior weight for warehouses and factories is only reckoned at $2\frac{1}{5}$ cwt. per superficial foot there was evidently great excess of strength, considering the proportion of 4 in. of breadth to 10 ft.

I must not dwell longer on this subject, or you will fancy I can never get down from my hobby. I do hope, however, that those who have the opportunity will try really testing experiments on concrete in this sort of application, and publish them for the benefit of the profession. I feel rather confident that the result will be, that floors and ceilings combined can be constructed of concrete, which shall rival any other form of material as regards price, strength, and economy of space.

I think it desirable to add a few words as to precaution which may be used in lessening the tendency to catch fire in buildings which are not in their nature actually non-inflammable or intended to be so. Whenever timbers are exposed, it is very desirable to cover them with a coating of common whitewash, which acts doubly as a preservative, both by excluding air from the timber, and from its non-conducting power. This will, of course, be of no use when a fire has once been kindled and got to a head; but in case of fire seconds of delay in kindling it or communicating it are of vital importance. In many a workshop or factory, if the floors and roof timbers were kept well whitewashed the risk would be much diminished. Special precaution should be taken about the floors and fireplaces: there is frequently great carelessness in trimming joists and fixing grounds for skirting, etc. It would be very desirable always to skirt chimney-breasts in cement or plaster, and to fill in the place under the hearthstone with cement concrete. Ceilings, again, should be formed with much stronger laths and better nailed; and if about 2 in. of rough mortar, the coarser the better, were laid over the laths between the joists, it would be found very difficult to set fire to them—they would resist for a considerable time even a fierce fire underneath. Again all rooms should have a good height, otherwise the constant operation of gas-lights is to prepare the timber of the ceilings for combustion on the most rapid scale, if the opportunity be once given. As regards all stoves, great attention should be paid to their being so arranged as to avoid all risk arising from the heat of the stove itself, its flue-pipe, or its ash-pan; no stove should be considered safe the flue-pipe of which cannot be heated to redness with perfect safety to the building. But in all ordinary buildings the most important point to attend to is the staircase: it should be, if circumstances will admit, closed at top or bottom, cut off from the passages leading into the rooms, and in the construction of it it is very desirable to lath the soffits with extra strong laths, and fill in from the upper side with concrete, so that all the space at the back of the riser and under the tread shall be a solid mass of non-inflammable material. Such a staircase would probably stand and bear the weight of persons ascending and descending under circumstances where an iron or stone staircase would be destroyed or useless.

A TORPEDO DETECTOR.

From the "Times," London.

Captain Harvey, R. N., the inventor of the towing Otter torpedo, lays it down as a primary rule in his tactical instructions for the use of the weapon, that an attack upon ships by torpedoes should always be made, if possible, under the cover of night. The Naval Torpedo Committee have given the subject of attack by torpedo boats at night upon ships at anchor considerable attention, and have proved by experimental practice that in the majority of instances the torpedo attack upon the ship must be successful. The Monarch, one of the ships experimented upon, was anchored at Spithead, and on one occasion was considered to have been made almost impregnable against any attack by a strong crinoline framework of booms and spars built up round, supplemented by her boats rowing guard round her within hailing distance. The ship had also the advantage of knowing that a boat torpedo attack would be made upon her, and the time when the attack might be expected. Notwithstanding these important advantages in the ship's favor the torpedo boats—steam pinnaces—burst through the Monarch's cordon of guard boats, got over the difficulty of the projecting crinoline spar defence, and struck the frigate with their dummy torpedoes. These results proved that any vessel lying at anchor at night must be fatally deficient in her defensive powers in a want of means for searching with lightning quickness and distinctness the surface of the water to a considerable distance around the ship. To supply this want effectually, Mr. H. Wilde, of Manchester, some time since submitted to the Admiralty a proposition for the use of one of his electro-magnetic induction machines, fitted with a proper apparatus for projecting the beam of light produced upon distant objects. One of these machines has been fixed on board the Comet, twin screw gun vessel at Portsmouth (one of the short and light draught boats carrying one 18-ton gun on a raising and lowering platform, on the Armstrong-Rendell plan), and was tested during the nights of Thursday and Friday last, under the supervision of Captain Boys, and members of the Naval and War Office Torpedo Committees, with the most complete success.

On Thursday week the Comet left Portsmouth harbor for the eastern entrances to Spithead, from the Channel, at about 8 P. M.; but half an hour before leaving, a first experiment was made with the machine and its projector lens in throwing the beam of light round the upper part of Portsmouth harbor. The results were startling. The gunnery ship Excellent, with her tenders and the boats alongside and at the boom-ends, the long lengths of the sea well enclosing the dockyard extension works, the mud-banks—it being nearly low water—the Asia and the vessels about her, and further away into Fareham creek, her Majesty's yacht Victoria and Albert, the

Glatton monitor, and the few men-of-war boats moving about between the ships at the time, all stood out with wonderful distinctness as the electric light touched them. But, beyond all the others, the Glatton, in her French grey paint, given her as an invisible dress at certain distances by daylight, shone out in weird splendor. When the Comet subsequently left the harbor and had taken on board the members of the Torpedo Committees off Southsea, she steamed to a position off Brading and the east end of the Isle of Wight and anchored, attacks being then made upon her by two steam pinnace torpedo boats, from directions, of course, unknown on board the Comet. When the boats had been away a certain time the electric light was brought into play, its beam sweeping the surface of the water and in each instance discovering the torpedo boats before they could lessen a mile's distance between them and the Comet. Discovered at such a distance, their attack, of course, was considered to have utterly failed.

On Friday the Comet was anchored in Stoke's Bay, near the west end of the measured mile, and buoyed off for the speed trials of her Majesty's ships. Captain Boys and the members of the Torpedo Committees made a number of experiments with the light, upon which official reports will be made. On Friday, as on Thursday, no boat could approach the light within a mile without being at once discovered.

Mr. Wilde's apparatus consists of two parts—an electro-magnetic induction machine for producing the electricity, and an arrangement for regulating the light produced by the current and projecting it upon distant objects.

The electro-magnetic induction machine is founded upon a somewhat paradoxical principle—that magnets and electric currents indefinitely weak can produce magnets and currents of indefinite strength. The machine consists of a circular or cylindrical framing of cast iron, round the interior of which are arranged a number of electro-magnets at equal angular distances from each other. A cast-iron disc is mounted on a driving shaft running bearings fitted to each side of the framing, and carries a number of armatures revolving before the electro-magnets. A slight charge of magnetism is imparted to the electro-magnets before the machine is used for the first time, by transmitting a momentary current through the wires surrounding the iron cores, or by touching their extremities with the poles of a permanent magnet. This initial charge is always retained by the electro-magnets, and is the basis of the augmentations of the electricity and magnetism produced by the rotations of the armatures. As the armatures revolve they become slightly magnetized in their passage between the poles of the electro-magnets, generating weak currents in the insulated wires surrounding them. These currents are transmitted by means of a commutator through the wires surrounding the electro-magnets, so as to increase their magnetism, until, by a series of actions and reactions of the armatures and electro-magnets on each other, the magnetism is exalted to the highest degree of intensity and the most powerful currents of electricity are produced. A small fraction of the current thus produced is sufficient to sustain the power of the electro-magnets, while the major portion of the current produces the light. The machine on board the Comet is 28 in. high, 34 in. in length, and 21 in. in diameter. Its weight is 11 cwt. About 4-horse power is required to drive it a velocity of 600 revolutions per minute, and this driving power is obtained on board the Comet from the fly-wheel of the small engine that raises and lowers the 18-ton gun and its platform. At this velocity the current will fuse an iron wire 6 ft. long and 0.05 in. in diameter, and will burn carbons ½ in. square. In this machine the alternating current is used for producing the light, past experience in lighthouse illumination having proved it to be greatly superior to the direct or continuous current, since it has the important advantage of consuming the carbons equally, and thus always retains the luminous point in the focus of the optical apparatus used in connection with the machine. The alternating current also dispenses with commutators, and the destructive spark on the rubbing surfaces is also avoided when the light may be accidentally extinguished, or when the circuit becomes broken from any other cause. Copper wire conductors are laid from the machine along the Comet's deck, from the position of the machine over the engine-room to the fore part of the vessel, for the transmission of the electric current to the apparatus where the light is regulated and projected from. All the arrangements on board the Comet in this respect have been made to render the light available for naval purposes whether as a torpedo boat detector or otherwise, and with this view a simple mechanical regulator arrangement, worked by the hand, has been substituted for the delicate mechanism by which the carbon poles have hitherto been automatically adjusted. The carbons as they consume are made to approach each other by means of right and a left-handed screw, the screws being made to act independently of each other, so as to allow of the adjustment of the carbons to the focus of the optical apparatus used for projecting the light. The regulator with its carbon points is placed in the focus of a catadioptric lens, which parallelizes the divergent rays of the light into a single beam of great intensity. The lens, with the regulator, is pivoted horizontally and vertically on the top of a short iron column fixed on the forecastle bulwarks of the Comet. The box holding the lens and regulator with the carbons is thus well elevated above the bows of the vessel, and the beam of light, by the action of a quick screw adjustment, may be directed to every part of the horizon and cover any object within the vertical angle of its range. As the carbons only require regulating once in two or three minutes, this is effected by the man in charge without any interuption in the movement for directing the beam of light.

Such is the "Wilde electro-magnetic induction machine," and the nature of the work it did on Thursday and Friday nights, so far as it is necessary to enter upon in a paper written only to explain its powers as an electric light for the navy. It is almost superfluous to observe, however, that any ship of war having one of these machines on board would find its light-producing powers of inestimable value for other purposes than its employment as a torpedo vessel or boat detector in an ancorage at night. The cost of working such a machine is a not unimportant item in any official consideration of its usefulness. Mr. Wilde, in his official communications with the Admiralty, has estimated the cost of producing the light from his machine on board the Comet, exclusive of the driving power obtained from the vessel's engine room, at only 4d. per hour.

RIVER POLLUTION—THE REPORTS OF THE COMMISSION.*

From "The Building News."

The author stated at the outset that in this paper he should deal only with two reports, viz., those of the Royal Commission of 1865, which treated of the Thames and Lea. No more momentous questions ever engaged the attention of a Royal Commission than the pollution of rivers and the water supply of the people, and it was to be deplored that so much labor as had been bestowed by the Commissioners had borne so little fruit. It was to be hoped that the Government would soon find time to deal in a practical way with such important questions. It had been said that we ought to thank Providence for the fact that wherever there was a large town, there also was provided a river close by. This was a very handy arrangement for getting rid of the town sewage, even at the cost of poisoning the people living in towns lower down the stream; although one fact brought out by the report of the Commissioners in connection with this part of the subject was worth noting, viz., that except in a few cases, however bad the state of a running river might be, we were not able to trace directly any outbreak of disease to it. The cesspool was indeed the unfailing source of every sickness, as though Death itself were condensed therein; but the foul river seemed to act more gradually, and rather by lowering the health of a district than by causing epidemics. Mills and manufactories made the same use of the rivers as the towns, and each loudly blamed the other for the nuisance. The Royal Commission of 1865 was addressed to Robert Rawlinson, John Thornhill Harrison, and John Thomas Way, Esquires, and directs the Commission to inquire "How far the present use of rivers or running waters in England for the purpose of carrying off the sewage of towns and populous places, and the refuse arising from industrial processes and manufactures, can be prevented without risk to the public health or serious injury to such processes or manufactures, and how far such sewage and refuse can

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*A paper read before the Civil and Mechanical Engineers' Society by W. F. Butler.

be utilized or got rid of otherwise than by discharge into rivers or running waters, or rendered harmless before reaching them; and also for the purpose of inquiring into the effect on the drainage of lands and inhabited places of obstructions to the natural flow of rivers or streams, caused by mills, weirs, locks, and other navigation works, and into the best means of remedying any evils thence arising?" The letter of the Home Secretary suggested that the inquiry should include selected river basins, illustrating different classes of employment and population, and named six subjects of inquiry, viz.: (1) The Thames Valley, as an example of an agricultural river basin, from which, after extensive pollution, is mainly derived the water supply of the metropolis; (2) the Mersey Valley, as an example of a river basin most extensively polluted by all kinds of manufacturing refuse; (3) the Aire and Calder Basin; (4) the Severn Basin, as connected with the great seats of the iron trade; (5) the Taff Valley; (6) a river basin comprising a mining district in Cornwall. The subject of water supply was added in consequence of a letter from Mr. Charles Neate, M. P., to the Home Secretary. The first river, therefore, which claimed the attention of the Commissioners was the Thames. The length of the Thames is 201 miles, and its basin extends its greatest dimension east and west from Cirencester, in Gloucestershire, to Shoeburyness, in Essex, and its greatest breadth, north and south, from Priors Marston, in Warwickshire, to Fernhurst, in Sussex. The area of the entire basin is 5,162 square miles, or 3,303,680 acres. The annual rainfall about Thames Head is from 27 in. to 30 in., and in London about 25 in. The tributaries of the Thames above Hampton are, on the north side, the Churn, Coln, Windrush, Evenlode, Cherwell, Thame, and Colne, while from the south the river receives the waters of the Ray, Cole, Ork, Kennet, Lodden, Wey, and Mole. On the main stream of the Thames above Hampton there are 217 towns, villages, and hamlets, with a population, in 1861, of 172,120. There are also 69 mills, while on the tributaries there are 784 towns and other places, having a population of 715,968, with 199 mills. The tributaries below Hampton are, on the north, the Yedding, Brent, Lea, and Roding, and on the south, Hog's Mill, Wandle, Ravensbourne, and Darent. There are also eleven canals joining the Thames at various points downward to Gravesend. The dry weather flow of the Thames is almost entirely spring water, there being neither lakes nor marshes to store up flood water. Were there such natural reservoirs of sufficient size, it is probable that the floods to which the Valley of the Thames is subjected would be in a great measure prevented. The dry weather flow of the Thames at Wolvercot, three miles above Oxford, is estimated to be about 50,000 gallons per minute, which quantity is increased in ordinary floods to about 223,000 gallons, which was again increased, after five days' rain, during which there fell 1.456 in. of rain, to about 505,000 gallons. Owing to the neglected state of the river, floods, especially those which come in summer, are very destructive. Proper attention to weirs and locks, the construction of sufficient land drains parallel to the river, and the formation of a system of embankments where required, would go very far to render floods harmless. The Thames has been a navigable river time out of mind, and before railways were made a large trade was carried upon it. Now, however, the navigation of the Upper Thames is at an end, for the river is full of shallows and islands, the banks are neglected, and the locks will neither open nor shut. Between Oxford and Lechlade all navigation may be said to have ceased, not altogether from the cause usually assigned, viz., railway competition; for the Lea is a river exposed to much keener railway competition, and was never in a more flourishing condition. The locks on the Upper Thames are in a ruinous state, nor are there any funds with which to put them in order. The weirs, too, are frequently owned by the millers, who, when they want water, fix boards to the weir to increase its height, of course at the risk of flooding the adjacent land. Many of the weirs, too, are totally inadequate to pass the requisite volume of water in flood times, so that the river is choked at these points, and flooding is a natural result. Any form of curved weir does not seem to be adopted, and both locks and weirs are old-fashioned and quite worn out. There are, as before stated, 61 mills on the main stream of the Thames, several of which are paper mills, causing a great deal of pollution in the river. Many of the weirs belong to these mills, and though the millers are prohibited from raising high-water mark above a certain fixed level, yet, as there seems to be no one to enforce the prohibition, it is not always obeyed, and from this cause flooding and injury to land results. The unchecked growth of weeds, especially in the Upper Thames, is a serious evil. Few persons ever take the trouble to cut them, and if they do, no one seems to think of removing the cuttings from the river; they are simply left to float down and choke the next weir, or clog the next mill's hatches or wheel. In many cases they help to form aits or banks, upon which, when sufficiently large, the nearest riparian proprietor or miller plants osiers for his profit; and so the numberless islands are continually increasing. The navigation of the Thames below Teddington has not undergone the same vicissitudes as the river above that point; nevertheless, there are many remarkable facts connected with it. For instance, the removal of Old London Bridge lowered the water at Richmond 1 ft. 4 in., or, as one witness stated, 3 ft., and the dredging carried on in the pool tends still further to diminish the depth of water higher up, so that navigation can hardly be carried on above Putney at low water. From this cause, and from the great extent of foreshore which is left dry at low water, a cry has arisen for a lock and weir at Isleworth; but there are several objections to this. If the proposed weir were erected, it must shut out the tide for a length of about five miles, which would cause a serious diminution of the scouring power of the river below the weir. This was not to the same extent the case with the Teddington weir, as the tide would seldom flow above this point. Already the scour of the river through London is not too great, as may be seen by looking at the extensive deposits of mud which are forming beside the new Embankments. Any diminution of the volume of water might have the most serious consequences. Again, by the raising of the water level, a large tract of valuable land would be permanently inundated, and the drainage of the whole district seriously affected. One of the witnesses stated also that one result of the proposed weir would be to leave the river nearly dry below it to Putney. It seems pretty certain that if a lock and weir were erected at Isleworth another would be required about Putney, which would shut out an additional seven miles of tide water. These weirs must be full-tide weirs, for if they were so constructed as to allow of a portion of the tide passing over, there would be such a deposit of mud from the still water as would require constant dredging. One witness stated that he found even now a deposit in the still parts of the river near Kew, forming at the rate of 1 in. per month. It would be possible so to lower the bed of the river between London Bridge and Teddington, by dredging, as to insure sufficient water at all times for navigation purposes; but if this were done, more and more of the foreshore would be left exposed at low water. Altogether, the Thames between London Bridge and Teddington weir affords a very nice problem for the Engineer to the Conservancy to solve. Possibly the difficulty might be overcome, though at a great expense, by canalizing a portion of the width of the river, leaving the remainder for the tide and flood waters. The canal, when the land would admit, might be carried inside the river bank. Of course this canal could only be used for through traffic, and for that intended for one side. Barges going to or from the wharves on the other side must still pass up the old channel. Mr. Butler then passed on to consider the numberless pollutions to which the river is subjected, as detailed in evidence before the Commissioners. As this portion of the subject has already been very fully discussed in the "Building News," we need not here say more. Land drainage, sewage irrigation, and the abstraction of large quantities of water from the river for drinking and manufacturing purposes, are all topics which came within the scope of the Royal Commissioners—who also recommended that the anomalous and mysterious body, known as "Thames Commissioners," should be abolished, and that the sole jurisdiction over the river be vested in the Thames Conservancy. Passing on to consider the River Lea, it appeared that though is is the source of a very large proportion of the potable water of the metropolis, it is frightfully polluted. The navigation, however, is exceedingly well cared for by a body called the River Lea Trustees, who exercise jurisdiction over the river. The Lea, although it has to contend with the Great Eastern Railway running alongside nearly all its length, increases its traffic year by year. The locks and other navigation works on the Lea were laid out by Smeaton between 1770 and 1780, and that celebrated engineer designed a great number of locks between the Thames and the level of Hertford Pond, with a total rise of 119 ft. above Trinity high-water mark. There are also six extra flood and tidal locks, or stop-gates. The locks on the Lea are thought to be among the first constructed in this country. The locks as constructed by Smeaton were made with waist, platforms, and foundations of timber; but the upper and lower recesses for gates were of brick, with piling between. The piles were about 16 ft. apart, the spaces being filled up with horizontal camp-sheeting. These locks had a maximum of 3 ft. draught of water, and a rise of about 4 ft.; their width was 13 ft. and the total length from centre to centre of the gates was 96 ft. Having described the course and tributaries of the Lea, and given other interesting and valuable information, Mr. Butler brought his paper to a close.

THE STROPHOMETER OR SPEED INDICATOR.*

By T. A. HEARSON, Esq , Assistant Engineer R. N , Associate.

From "Iron."

Nearly all engines, and especially those which propel ships, are subject to great and incessant fluctuations of speed, and it is desirable to have an instrument which will indicate by a pointer on a marked dial, not the momentary but the mean rate of revolution of the engine, or the number of turns which would be counted in a minute. Attempts to ascertain the exact velocity of rotation by the amount of deflection produced in a spring, by the centrifugal force generated in a revolving weight, have naturally resulted in an excessive oscillation of the pointer rendering the machine almost useless. Before we can obtain a valuable indication by these means, it is necessary that the weights in which the centrifugal force is generated should revolve with an uniform velocity equal to the mean speed of the engines.

In the strophometer, fly-wheels driven by friction are used, the action of which is to eliminate the smaller and more frequent variations of speed which are only momentary, and obtain an almost constant velocity of rotation. Its construction and manner of working is this.

First, there is a steel spindle, having a groove cut along the upper part of its length, and secured firmly by a nut at the bottom to a bracket, which may be fixed in any convenient part of the engine-room, ship, or factory. On the lower part of the spindle a steel-bushed pulley revolves freely, a gut being led round it from the shaft, or any revolving portion of the machinery. Resting on the pulley and running freely on the spindle, is a steel-bushed fly-wheel, a thin steel washer with a large bottom and small top being placed between, so as to give a small bearing surface for the fly-wheel. The under face of the fly-wheel is recessed, and into the recess there project up from the pulley two studs, having one of the ends of a pair of chains connected to them; the other ends fly out by the centrifugal force against the inside of the rim of the fly-wheel, and act frictionally thereon so as to make the fly-wheel revolve. Similarly, chains from studs on the lower fly-wheel impart motion to another steel-bushed fly-wheel, also running freely on the spindle, the bosses being separated by a thin steel washer. With these driving arrangements the inertia of the fly-wheels will prevent them from being too easily affected by the changes of speed which are not persistent; and if the small variations are not sufficiently obliterated by the lower fly-wheel, they will be more completely so by the upper one.

Surrounding the spindle above the upper fly-wheel is a helical wire spring, the bottom being fastened to the fly-wheel and the upper end to a boss or collar, which may slide up or down and revolve freely round the spindle. The boss is also connected to the fly-wheel by two pairs of jointed links. These links carry balls on their middle joints, and the action of the centrifugal force in moving these balls outwards, causes the boss to be the more drawn down, and the spring to be more compressed, the greater the speed is. The movement of the boss is communicated to the pointer by means of a bent steel wire (which nicely fits the groove and clasps the upper and lower edges of the boss) jointed to a light

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* A paper read before the Institution of Naval Architects.

rod with a rack on the upper end gearing into a small pinion on an arbor carrying the pointer, which sweeps over a marked dial carried by the bracket on a spindle.

The amount of the frictional driving power produced by the chains increasing with the increased velocity and centrifugal force, will be always a little greater than the increasing resistance to rotation, which the fly-wheel receives from the air—the constant driving friction of the boss being made sufficient to overcome the constant resistance of the friction of the spindle. The difference between the driving power and the resistance is thus very nearly constant for all speeds, and bears some proportion to the inertia of the fly-wheels, depending on the amount of the fluctuation of speed the engine experiences, and the steadiness required in the pointer. There being no permanent slip, the upper fly-wheel is made to maintain an almost uniform speed equal to the mean speed of the pulley; and thus a steady indication is obtained. The pulley and fly-wheels may, when desired, be joined together by a pin. Then the fly-wheel will rotate exactly with the engines, and the fluctuations indicated by the pointer may be observed. It will be found that the mean position of the pointer is the same as it would attain when the pin is removed. By this experiment the amount of chain required to drive the fly-wheel is determined. If more than is necessary be used, the needle will occupy the same mean position, but will oscillate about it more or less. If there be less chain than required, the resistance being in this case greater than the driving power, the fly-wheel will fail in attaining the mean speed of the pulley, and the pointer will not reach the mean position before found.

One of these strophometers has been at work in H. M. S. Agincourt for about nine months, enabling the engineer to tell at a glance and within a quarter of a revolution, the speed of the engines. When the ship in a rough sea is pitching a great deal, and the engines experiencing very great fluctuations of speed, the pointer may be seen to move slowly about the mean position each way within the limits of half a revolution; a steadiness sufficiently exact. The want of a machine of this kind was most urgently felt in ships of war when steaming in company with others. To keep accurate station one with another, a most careful and frequent adjustment of the speed of the engines is necessary; performed by opening or closing the admission-valve a trial amount, and ascertaining the error, if any, by counting with a watch, and then correcting it. This, when often repeated, is a tedious process, and doubly so in ships with twin-screw engines. When performing steam evolutions the frequent alterations of speed required renders this instrument extremely valuable. It shows the change of speed with the change of steam pressure, the throttle valve being unaltered; and the change of speed due to the change in the force of the wind, or the set of the sail; the steam pressure being constant. The effect on the speed of more or less injection water is also shown by it. It enables one to note the speed at the instant of taking an indicator diagram, and so the correct indicated horse power can be determined. It may be fitted on deck as well as in the engine-room, that the officer on watch as well as the engineer in charge may know the speed of the engines. Although being particularly adapted to indicate the speed of marine engines, it may be advantageously employed for other purposes.

It may be used to indicate the speed of a ship in the following manner: A small screw being fitted outside, and at a little distance from the side of the ship, so as to turn with the pressure of the water due to the onward movement; and a light gearing being led from it to a machine of this kind in the ship; the many and great fluctuations in the speed of the screw, produced by the waves, and the rolling, pitching, and yawing of the ship being deleted by the machine, the speed of the ship in knots per hour may be indicated by a pointer on a suitably marked dial. It can be designed so that the screw may be lifted out of the water in weather rough enough to endanger its safety. The strophometer would be useful in locomotives, for telling the speed of the train in miles per hour. The fluctuations in this case being small, one of the fly-wheels may be dispensed with. The machinery used for spinning and weaving should, to work efficiently, keep an almost constant speed. The application of this instrument would test the presence or absence of this requirement. Here the range of speed being small, the whole of the dial should be utilized by having a small pinion. Each revolution may be subdivided, and the speed indicated with very great accuracy.

HYDRAULIC MOTORS.

From "The Engineer."

There can, we think, be little question but that the use of hydraulic power as a motor is daily on the increase, and that as its merits and capabilities become better understood and developed, the ratio of that increase will be considerably greater in the future than it has been even of late years. The whole subject is one which, as our readers know, has not in any wise escaped our attention as regards the general principle connected with the theories involved, and the illustrations and descriptions which from time to time we have given of the different machinery, inventions, and appliances that have been proposed and tried with certainly varied success, will have kept before those same readers a more or less general view of the concurrent history of the adoption of hydraulic power as a motor. It is scarcely necessary for us to point out, or, indeed, even to refer to the different forms which have been given to hydraulic machines by their inventors. The ordinary overshot, breast, and undershot wheels so common at one time in this country are of course familiar to every one; it is not, however, of such applications as these that we propose to treat, but rather of those instances in which water pressure as a motive power has been adapted to engines and machinery. We do not at all pretend to give even a sketch of the history of these, but we find in looking through some old notes that in 1803 Trevithick erected at the Alport Mines an engine in which the water was admitted first upon one face of the piston and then on the other, the inlets and outlets being opened and closed by two smaller pistons operating at the sides. This machine worked continuously during forty-seven years—*id est*, until the year 1850, when it was removed on the abandonment of the sett. We find, too, that at the same mines Mr. Darlington erected a water engine having a cylinder 50 in. in diameter and a 10 ft. stroke. In this case, the cylinder, the piston, and pump-rod, being in one continuous piece, was placed directly over the pit, the pressure on the piston, coming from a head of water 132 ft. in height, equalling about 58 lbs. to the sq. in., or, say, 50 tons on the whole area. With a plunger 42 in. in diameter, water was raised at the rate of 5,000 gallons per minute from a depth of 22 fathoms, the water for the motive engine being in this case admitted on one side of the piston only through cylindrical valves, allowing a full flow for seven-eighths of the stroke, when they began to close, and a small valve then opened to allow sufficient water to pass to complete the stroke. The same gentleman afterwards erected another engine nearly similar in its general construction to this, but working under a pressure column 227 ft. in height. The average speed of this latter machine was 80 ft. per minute, but this could be run up to 140 ft. per minute.

Sir William Armstrong, in addition to his well-known water cranes, has, we believe, made use of water pressure from natural falls to produce rotary motion by means of double cylinders and pistons with slide valves, in some degree similar to those of high-pressure steam engines. There is, however, a difficulty about working any of these machines; for although the absence of any sensible elasticity in water renders motion produced by it in engines susceptible of perfect control, yet that same inelasticity is apt to cause sudden shocks and blows to the moving parts of water engines, if they be constructed on the same principles as those for such elastic fluids as steam or air. This said difficulty has, however, been in great measure overcome by the use of relief valves, or their equivalents. Another well-known mode of utilizing hydraulic power is the turbine; the works at Bellegarde, which are now being illustrated in our papers, constitute an excellent example of the most recent application of this form of hydraulic mechanism. Our purpose at present is to direct attention to proposals and arrangements for a very extended application of hydraulic pressure, which have been put forward by Mr. R. H. Tweddell, whose system of riveting, both by fixed and movable machines, we have already noticed. This last proposition deserves consideration, the more especially since the general tendency of practical constructors is certainly to concentrate operations in one spot, thus rendering area of manufactory so great that there arises a certain difficulty in distributing the central power by shafting or gearing. In such cases as these, Mr. Tweddell proposes that water-pressure mains shold be laid down on a regular plan, and branches carried therefrom, as required, to the different individual tools—such as planing and slotting machines, and the larger class of lathes; under which arrangements there would be very considerably less loss of power in transmission than that sustained in a system of shafting, belting, or gearing; for, in fact, it only involves the friction of the packing in the pumps, the accumulator, and the water in the pipes, which has been found to be little over 1 per cent. On this head, however, it may be remarked that for the smaller classes of rotary machines Mr. Tweddell is rather in favor of the use of shafting, which, he says might probably be advantageously driven from the pumping engines, in which cases he would recommand the use of an engine of Brotherhood's three-cylinder type, the adoption of which to such purposes has already been under consideration.

It will be seen from the foregoing that the idea of using hydraulic power as a general motor is a sufficiently extensive one, inasmuch as it embraces in a whole the supplying of power to almost every variety of machine or tool, and that in a manner which would render it always available, and that, too, with economy; for the power once stored up continues at the disposal of the operatives without any further expense, whilst if steam be the directly acting agent, its maintenance at a certain pressure, so as to be equal to the task requiring performance, is a matter of charge in some form or other, and, especially when the power needed is only intermittently used, entails considerable waste and expenditure.

There is unquestionably as yet a great deal to be done in the development of hydraulic machinery; but we venture to think that infancy is the infancy of a giant, and that by and by, when we come to see its strength put forth and its great usefulness demonstrated, we shall feel how much our thanks are due to the pioneers whose investigations and researches are daily contributing towards such results.

CONSTRUCTION OF CONICAL ROOFS.

From "The Builder."

On a previous occasion we reported briefly the discussion which took place at the Royal Institute of British Architects after the reading of Mr. Scott Russell's paper on the "Central Dome of the Vienna Exhibition Building." We now add in full Mr. Scott Russell's reply, as containing much interesting matter:—

I will now endeavor to answer the points on which you have asked for information, as concisely as I can. I am afraid when I say anything it may have the appearance of being too dogmatic, but I hope you will not accept it in that way. I feel deeply grateful to gentlemen who have deduced the points and exceptions and difficulties which they have done, because in answering them I think I shall give them the conviction that the cone possesses greater merit than I could have satisfied them it possessed if they had not been good enough to make these objections. I will now run through the matter as quickly as I can. In the first place, permit me to say that almost every one of the suggestions you have made, as to the alteration of the cone, and the different views of its theory, are perfectly true; and allow me also to say, I have confined myself in that article to the pure cone, because if I had gone out of the pure cone into the region of new structures, the quantity I could have laid before you is so enormous, that you would have been lost in a maze of confusion, as I was; and I had enormous difficulty in selecting out of the multitude of applications of principles of this kind the form of the cone at Vienna. You would imagine men of taste would be in love with the beautiful spheroidal form, and would not take the strictly straight cone when they might have the more beautiful spheroidal form. I will tell you how I came not to adopt it: I drew it out and discussed its peculiar qualities, and it was only the peculiar state of conditions which led me to adopt this form, which I think is not so beautiful as if I had made it spheroidal. A multitude of questions arose. It has been properly said, that time is a great element in practical construction, and engineers and architects are often obliged to abandon what they wish to do, by want of time. Now, want of time and want of money are two things against the spheroidal dome. I will tell you why. The conical form has enormous advantages in construction. All the iron plates are plates of single curvature—straight one way, gently curved the other. What is the consequence? We can put between them rollers, we can manufacture them by hundreds, and bring them out ready for the building. Take a surface of double curvature; you have to heat it in the fire, you have to cut its edges to a peculiar surface, you probably encounter great difficulty requiring much time to surmount, and if you have to do it, it is always badly done; whereas my cone can be manufactured by machinery, on the most simple but still most perfect mathematical principles. The reason why I prefer an absolutely straight cone to the cone with curvature is this: Mr. Penrose has touched upon the point. I have shown you that all my cone longitudinally is in compression—that all my cone circular-ways is in tension. Now a straight column under compression is much stronger than a bent column, and therefore that part of the cone in compression is far stronger if it is straight. The next point has been very properly stated, viz., that the ribs of this cone are very much deeper than you would imagine, from investigation of the cone itself. You are correct. The ribs of the cone, as originally designed, were much shallower than they are now. Why were they altered? Simply for the reason Mr. Crace has stated, that all the conditions of the original design were altered. The cone was made for being put upon masonry or brickwork, which was to have been carried out to the edge of the cone, and the cone was to have been set upon that. Then the chance of the cone changing its form was very small, and these ribs or rings which have a peculiar function with reference to columns had no such functions when resting on masonry, and therefore were very small. These girders were enlarged, because it was agreed, from circumstances of time, to sweep away the whole of the solid foundation; and one fine morning I was told "you are not to have a wall to put the cone upon; therefore, you must stick it upon iron columns in the best way you can." Then to arrange the iron columns to carry the buildings, but to carry the cone, and that resting upon solid masonry foundations, are two things totally and entirely distinct. To sum up the whole question with regard to cone and girder, permit me to say, that these girders were by some people thought very strong when they were put up. Only there came a little wind after they were put up, and people who went there saw a slight vibration in the wind which satisfied them that the girders must come down if the weather were at all tempestuous. It was only after they got the cone to rest upon, that they became part of the cone. It was only then they acquired any strength at all. What they have is great strength in their place; out of their connection with the cone they have none. If you take the great thickness of the girder, which is more than double what was designed, and then look at the length of it, 166 ft.; and then if you take the depth, not at the extreme end, but at the centre of gravity, where the strength is, you will find that these beams, which you think strong, are hopelessly weak to carry any structure, and then you will see that the beams had no strength till they became a part of the building. Coming more to the question of cones made of homogeneous metal, I may state that about three years before the opening of the Exhibition of 1851, I discovered that the cone was the successful structure which I have endeavored to show you it is; and it is a curious fact that I owe to you, and the reception which you gave to me in some papers I read, the original ideas of this cone.

I read to you some thirty years ago a paper, describing a principle by means of which the greatest number of spectators could be arranged in a large building, so that they should all equally well see any spectacle they were brought together to see. I then, I dare say, satisfied you that you could make a building in which 10,000, 20,000, or 100,000 people could have sat together, all witnessing the same spectacle, and each one thinking he had got the best place in the room. That was solving a difficult problem, but it was leading you on to the construction of very large buildings with very large audiences. Twenty-five years ago I read you another paper, which you discussed with the same friendly energy as you have this,—viz., on the question how to combine the largest number of people in a building so arranged that all sounds should reach the ears of those present in the most perfect and distinct manner. I also tried to explain certain principles by which echoes and influences which impede sound, and impede the clear hearing of separate sounds, might be removed. I hope I persuaded you that a building could be made in which 5,000 people could confortably listen to a single speaker, or an audience of 25,000 people could comfortably and agreeably hear a musical performance, but at the same time I know you did not believe that such buildings were necessary. But such buildings now have become so. You have had the Exhibition building of 1851, in which 100,000 persons were collected at one time, and you have had arrangements for the performances of music by orchestras of 3,000 persons, which have been listened to by 25,000 persons. [*A Voice.*—You cannot hear.] I have a deaf ear, but I could hear confortably with my deaf ear; and the orchestra which you have now in the Crystal Palace has carried out in the most perfect manner the theory I then gave you. I call attention to this theory of seeing and hearing, because it compelled me to think how I should roof this large building, and thinking over the problem you discussed, I arrived at this fact, "that if you are to have large amphitheatres to hold many thousands of people to view spectacles in London, in the way that the Romans did, you must make them with a cone, and I have invented this cone to cover your great buildings when you are pleased to build them, and if you make those great buildings in London—and you will have to do it, for buildings are growing larger every day—I expect you young men here will have to make roofs, not of 360 ft. span, but of 720 ft., conical roofs, and after that you will go on to make them 1,080 ft., and perhaps you will not go farther in your lifetime, but I undertake to say the task will be easy, and the cost what in those days will be called moderate."

Coming now to this small cone. The moment the idea had not only occurred to me, but was proved by investigation to be an idea in which you could use material much more economically than any other form I knew, I immediately developed the other form of cone to which you alluded. I saw that in my kind of building it would be possible to cut away all the dead matter of the cone, and put it into skeleton; and many years ago, in conjunction with an eminent member of your own profession, I designed a building in which all you have said was done: in which we throw away the entire homogeneous cone, in which we take away those trusses of which you speak, which are as old as wood construction. I have seen in the Rhenish countries the cone with wooden roofs applied to those semicircular Romanesque buildings, which for a time on the Rhine were competitors with Gothic architecture. I think I have seen wooden cones 250 ft. in diameter. In like manner you use iron girders, and do what you cannot with wooden struts, and you make a truss which requires no useless beams, no wasteful doubling, which is a perfect cone like my homogeneous cone, but I have always called that a skeleton cone; and, therefore, when you get these two circumstances together, if you are wise, you use a homogeneous cone for all it is good for, and a skeleton cone for all it is not good for: as it is not where columns are inserted below; and, therefore, you add these additional struts at the point where the local strain requires it. If you construct a cone with large foundations and continuous walls you find a solid, homogeneous cone is the cheapest and strongest form. If you make it on a small scale, where enormous strength is not required, you find the skeleton cone will answer all your purposes, and you can fill in with glass or any material you like. I like a homogeneous cone for this reason, —there is not one atom of waste. In common roofs you have slates and wood. The slates and wood do not carry themselves, but are a burden upon the structure. I have a large cone which justifies the use of iron plates, a half or three-quarters of an inch in thickness. I take these plates and form a roof of them alone, and then we have only to rivet and caulk the cone properly: and I believe it would stand without repairs for 100 years, and with repairs for 200 years; but you can modify this to any extent, and yet preserve to a large extent the principle of the cone. A gentleman mentioned the Exhibition of 1851 as having an iron dome proposed for it. You may remember that in 1851 many architects and engineers met and designed a building for the Exhibition. That was somehow eclipsed by Sir Joseph Paxton's wonderful invention, but allow me to say that a spherical dome can only be truthfully made by making curves of double curvature to every plate, and there is no difficulty except that you have to put your plates individually into the fire, and have them all hammered into ultimate shape. But I will show you a way of converting my cone into a dome at once, which was the very thing proposed in 1851. I would have built my cone in 1851: I had it all ready then. The cone I had ready was 400 ft. diameter. Why did I not? For this reason,—it happened I was one of the four persons who, with Prince Albert, originated the Exhibition of 1851. He insisted that I should be his secretary, and that I should be charged with the whole details of the Royal Commission. I had instantly to put all my plans into my pocket. I willingly assisted Sir Joseph Paxton to bring forward his. I told Mr. Henderson, Mr. Fergusson, and Capt. Fowke all about it, and they kept my secret, and nobody spoke about the cone till after Mr. Crace had prepared my designs for the Vienna dome.

About cones: I am glad to see the drawings of the cone which was then designed. That dome is what I would call a skeleton dome. First of all, I will show you an ugly dome, which I would (illustrating on board) make with a series of cones. If I were obliged to make a dome, and were ordered to make an ugly one, but retain, if possible, the same principle and the same economy which belong to my present dome, I would do it without incurring the difficulty of double curvature, in this way, by uniting a succession of cones of increasing taper. I should thus make what people call a dome. That you see is very ugly; but if I wanted to reduce the ugliness of it, then I could reconcile these patches by a filling of wood or other material, and thus I should have got a cone which, geometrically speaking, one would call perfect and beautiful. Now, in like manner, I was delighted when Professor Kerr suggested that we might have a great number of buildings of that sort, and ever since I studied the cone I have been astonished at the small number of buildings of that sort which exist. I am astonished to see in your buildings and in ours, the waste of material you go to, when you might do without it. Suppose this to be an enormous square building; suppose you wanted to cover this with a roof. Why not make a parabolic roof? Make it a cone with four flat sides. Make it an octagonal cone, which you could do by cutting off the corners and putting in girders. Then you have no occasion for ties. Captain Fowke did that in some of his beautiful buildings at Kensington. You can make a series of structures, all self-contained, all without waste of material, and all under certain circumstances beautiful. Gentlemen have alluded to oval buildings. You find them immensely disposed to change their form, but there are remedies which consist of addition of material. You must put in material to counteract that tendency to change of form. I will now tell you a secret, which I am sure you will keep confidentially, and not allow it to go out of these walls. It was proposed to me, once upon a time, to put a conical roof over the ancient amphitheatre at Rome. That would have been an architectural desecration. I went to a friend, who was an architect, and asked him, "What would you advise? I do not like to refuse these people. I am fond of the cone, and I should like to see it carried out: but would it not be a barbarism?" My friend replied, "Don't do it." I wrote back that I would not do it; but I had gone into the calculation, and I found there would have been no difficulty in putting up a cone, moderately expensive, which would have preserved the building for 200 or 300 years.

A gentleman asked me whether I would like to take away all the columns, or a few of the columns in the Vienna building, and some of my friends have asked how the building is supported. I introduce that as an illustration of the difficulties I had to contend with. I was informed that my solid walls were to be taken away, and that I was to put my cone upon a series of iron columns. I was aware that they would press upon the margin of the dome very much. I did not expect the slabs of concrete put into the gravel of the Danube to give way; but, as earthquakes have taken place there, I argued the possibility of another earthquake happening after my crack building was put up. So I tried to make my cone stand even without continuous walls and foundations; and even in case of an earthquake coming, I considered what would happen if one foundation of a column gave way. "Very well," thought I, "if one foundation gives way, what must I do? I must carry the edge of the cone on the two adjacent columns, otherwise it will sway, and come down." Therefore I have put a strong rib all round the edge carrying the cone from one column to another. But two columns might have given way. When two or three columns give way, this beam becomes too long to carry the columns. What must I do? I have only to keep a good thickness of metal in the cone itself, and then I should be extremely near having a catenary; that is, it is in one case a stretched chain. Take the case of three columns giving way. You will ask me, if three columns gave way, what will carry the cone above them? Professor Kerr did not like my terming the catenary an inverted arch. I do not think that is very strong. But it is not that which carries my columns. Think of the position. Three columns are taken away. Remember, the three corresponding columns on the opposite side are not taken away; therefore there is the weight of the cone on the other side balancing the preponderating weight on this side, and all united together by the catenary surface, out of which you can make any number of links you like. The chain is there, and this catenary I am now showing you is the catenary or parabola which has the whole of these columns hanging on this side, and the corresponding ones balancing them.

I have one final word to say, and that is, we have exhibited in a railway station not far from where we now are, a combination of engineering talent, with architectural skill, which is seldom witnessed, and there is no doubt the St. Pancras Station, with its roof of 220 ft. span, and its noble frontage, is a model of which your profession and mine may be proud. Only I must remind you that, if you want to go further, if you want much larger spans, you would find the circular ground plan has enormous advantages for a railway station, which no construction of railway stations hitherto appears to have had; and I recommend to your serious consideration the construction of a very large circular railway station with a domical roof. You will find it has enormous advantages. When you take the matter into consideration, you will see if you are required to design very large buildings in London, such, for instance, as on the great Embankment taken from the Thames, you will find a circular plan with a conical roof possesses infinite advantages, and if it were necessary to make buildings, such as railway stations, twice as long and broad, which I think would be foolish—but you must do it if your masters order it—all you have to do is put two circular roofs alongside one another instead of one oval, and the two close alongside will be much stronger than one oval roof equal to the area of the two.

THE ATMOSPHERE AS A VEHICLE OF SOUND.*

By JOHN TYNDALL, F. R. S.

From "The Engineer."

"On the Atmosphere as a Vehicle of Sound." At the instance of the Elder Brethren of Trinity House investigations on fog-signals were set on foot last May. They spread over several months, and Professor Tyndall embodied the scientific results of this inquiry in his communication to the Society. It is a remarkable fact in connection with this subject that, while the velocity of sound has been the subject of refined and repeated experiments, it is almost certain that, since the publication of a celebrated paper by Dr. Derham in 1708, no systematic inquiry has been made into the causes which affect the intensity of sound in the atmosphere. Derham's results, though obtained at a time when the means of investigation were very defective, have apparently been accepted with unquestioning trust by all subsequent writers; a fact which may be in some part ascribed to the *à priori* probability of his conclusions. Dr. Robinson, relying apparently upon the first-named authority, says, "Fog is a powerful damper of sound," and he gives us physical reason why it must be so. "It is a mixture of air and globules of water, and at each of the innumerable surfaces where these two touch, a portion of the vibration is reflected and lost." "And," he adds, "the remarkable power of fogs to deaden the report of guns has often been noticed." The same authority, as quoted by Sir John Herschel, says that "falling rain tends powerfully to obstruct sound." Falling snow also, according to Derham, offers a more serious obstacle than any other meteorological agent to the transmission of sound. All these generally accepted notions Professor Tyndall came to upset. His observations, both during the Trinity House inquiry and on the occasion of the

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* A paper before the Royal Society.

recent dense fogs (December), show that the generally accepted opinion as to sound in its relation to the atmosphere requires a careful revision. The first-named investigation was begun on the 19th of May, 1873. Gongs and bells were excluded from the experiments in consequence of their proved inferiority to other instruments of signalling. They were carried out with trumpets blown by powerfully compressed air, with steam whistles, guns, and a steam syren, associated with a trumpet 16 ft. long. Daboll's horn, or trumpet, has been highly spoken of by writers on fog signals. A third order apparatus of the kind was reported as sending its sound to a distance of from seven to nine miles against the wind, and to a distance of twelve to fourteen miles with the wind. The experiments were made with an improved instrument by Holmes of the first order. This instrument on one occasion became useless as a fog signal at three miles distance. At four miles, with paddles stopped and all on board quiet, they were wholly unheard. On the same occasion, at a distance of two miles from the foreland, the whistles became useless. The twelve o'clock gun, fired with a 1 lb. charge at Drop Fort in Dover, was well heard on the same day when the horns and whistles were inaudible. On the 20th of May Professor Tyndall said the permeability of the atmosphere had somewhat increased, but the steam whistle failed to pierce it to a depth of three miles. At four miles the horns, though aided by quietness on board, were barely heard. The superiority of the 18-pounder gun, already employed by the Trinity House as a fog signal, over horns and whistles, was on this day so decided as almost to warrant its recommendation to the exclusion of all the other signals. The atmosphere evidently showed itself capricious. Within the limits of a single day, even within a single minute, the air as a vehicle of sound underwent most serious variations. On July 1st an interval of twelve hours sufficed to convert the acoustically clear atmosphere into an opaque one, for on the following day even the horn sounds which were heard at a distance of ten and a half miles on the previous day could not be distinguished, with paddles stopped and all noiseless on board, further than four miles. The acoustic imperviousness of the 3d of July was found to be still greater than that of the 2d, while the optical purity of the day was sensibly perfect. The cliffs of the Foreland could be seen to-day at ten times the distance at which they ceased to be visible on the first, while the sounds were cut off at one-sixth of the distance. At 2 P. M. neither guns nor trumpets were able to pierce the transparent air to a depth of three, hardly to a depth of two miles. This extraordinary opacity was proved conclusively to arise from the irregular admixture with the air of the aqueous vapor raised by a powerful sun. This vapor, though perfectly invisible, produced "an acoustic cloud" impervious to the sound, and from which the sound waves were thrown back as the waves of light are from an ordinary cloud. The waves, thus refused transmission, produced by their reflection echoes of extraordinary strength and duration. On October 8th, a steam syren and a Canadian whistle of great power being added to the list of instruments, a boiler had its steam raised to a 70 lbs. pressure. On opening a valve the steam would issue forcibly in a continuous stream, and the sole function of the syren was to convert this stream into a series of separate strong puffs. This was done by causing a disc with twelve radial slits to rotate behind a fixed disc with the same number of slits. When the slits coincided, a puff escaped; when they did not, the outflow of steam was interrupted. Each puff of steam at this high pressure generated a sonorous wave of great intensity, the successive waves linking themselves together to a musical sound so intense as to be best described as a continuous explosion. The optical transparency of the air on this occasion was very great; its acoustic transparency, on the other hand, was very defective. Clouds blackened and broke into a rain and hail shower of tropical violence. The sounds, instead of being deadened, were improved by this furious squall; and after it had lightened, thus lessening the local noises, the sounds were heard at a distance of seven and a-half miles distinctly, louder than they had been heard through the preceding rainless atmosphere at a distance of five miles.

At five miles distance, therefore, the intensity of the sound had been at least doubled by the rain, a result entirely opposed to all previous assertions, but an obvious consequence of the removal by condensation and precipitation of that vapor, the mixture of which with the air had proved so prejudicial to the sound. A few days later on, and during a gale, it was sought to estimate the influence of the violent wind. It was found that the sound of the gun failed to reach the experimenters in two cases at a distance of 550 yards to windward, the sound of the syren at the same time rising to a piercing intensity. To leeward the gun was heard at five times and might have been heard at fifteen times the distance attained to windward. The momentary character of the gun sound renders it liable to be quenched by a single puff of wind; but sounds of low pitch generally, whether momentary or not, suffer more from an opposing wind than high ones. Taking the fluctuations of the atmosphere into account, Professor Tyndall is of opinion that the syren, performing from 2,000 to 2,400 revolutions in a second, or, in other words, generating from 400 to 480 waves per second, best meets the atmospheric conditions. The observations made afloat in the steam-tug Palmerston showed that the syren had the clear mastery over gun and horns. On one occasion, with a high wind and sea, the syren, and it only, reached to a distance of six miles; at five miles it was heard through the paddle noises. Among the incidental experiences of the observing party may be mentioned, that the shelter of the Coastguard station at Carnhill enabled them to hear gun sounds which were quite inaudible to an observer out of shelter; in the shelter also both horn and syren rose distinctly in power, but they were also heard outside when the gun was quite unheard. As usual, the sounds to leeward were far more powerful than those at equal distances to windward. On a day of extraordinary optical transparency (29th October) the atmosphere proved the reverse of acoustic transparency. The gun on that occasion was the greatest sufferer. At first it was barely heard at five miles, but afterwards it was tried at five and a-half, four and a-half, and two and a-half miles, and was heard at none of these distances. The syren at the same time was distinctly heard. The sun was shining strongly, and to its augmenting power the enfeeblement of the gun sound was doubtless due. At three miles and a-half subsequently, dead to windward, the syren was faintly heard; the gun was unheard at two miles and three-quarters. On land the syren and horn sounds were heard to windward at two miles to two miles and a-half; to leeward at seven miles; while in the rear of the instruments they were heard at a distance of five miles. The 30th of October furnished another illustration of the fallacy of the notion which considers optical and acoustic transparency to go hand in hand. The day was very hazy, the white cliffs of the Foreland at the greater distance being quite hidden; still the gun and syren sounds reached on the bearing of the Varne lightvessel to a distance of eleven miles and a-half. The syren was heard through the paddle noises at nine miles and a-quarter, while at eight miles and a-half it became efficient as a signal with the paddles going. The horns were heard at six miles and a-quarter. This was during calm. Subsequently, with a wind from N. N. W, no sounds were heard at six miles and a-half. On land, the wind being across the direction of the sound, the syren was heard only to a distance of three miles N. E. of the Foreland; in the other direction it was heard plainly on Folkstone Pier, eight miles distant. Both gun and horns failed to reach Folkstone. The experiments demonstrate that there are atmospheric and local conditions which, when combined, prevent our most powerful instruments from making more than a distant approach to the performance which writers on fog-signals have demanded of them. Professor Tyndall's investigations have given us a knowledge of the atmosphere in its relation to sound, of which no notion has been previously entertained. This is the first time that audible echoes have been proved to be reflected from an optically transparent atmosphere.

The real enemy to the transmission of sound through the atmosphere has been proved to be not rain, nor hail, nor haze, nor fog, nor snow—not water, in fact, in either a liquid or a solid form, but water in a vaporous form mingled with air, so as to render it acoustically turbid and flocculent. This acoustic turbidity often occurs on days of surprising optical transparency. Any system of measures, therefore, founded on the assumption that the optic and acoustic transparency of the atmosphere go hand in hand must prove delusive. Observations made during the recent fogs add the force of demonstration to others recorded above, viz., that they possess no such power of stifling sound as that hitherto ascribed to them. Indeed the melting away of fog on December 13th was accompanied by an acoustic darkening of the atmosphere so great that at a point midway between the eastern end of the Serpentine in Hyde Park, where a whistle was sounded, and the bridge, the sound possessed less than one-fourth of the intensity which is possessed on the day of densest fog. For more than a century and a-half congeries of errors have been associated with the transmission of sound by the atmosphere, and the subject certainly deserves all the attention Professor Tyndall has given to it. In regard to the instruments of the future this principle ought to be kept in view, that the source of sound be made so powerful as to be able to endure loss by partial reflection, and still retain a sufficient residue for transmission.

Of all the instruments hitherto examined, the syren appears to come nearest to the fulfilment of this condition, and its establishment upon our coasts would prove an incalculable boon to the mariner.

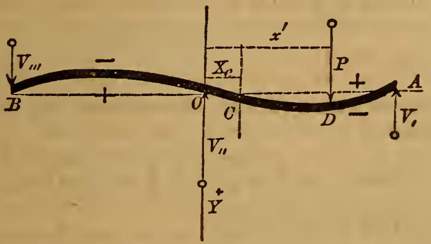
DISCUSSION OF THE APPLIED FORCES IN A DRAWBRIDGE.

By H. T. EDDY C. E., Ph. D., Princeton, N. J.

In order to compute the strains in the different members of a drawbridge covering two equal spans, it is necessary first to find the weight resting on each of its three piers. The weight on each pier is due to the live and dead load, and varies with every change in the position of the live load. The upward thrust of piers (which is equal and opposite to these weights), together with the live and dead loads, are the "applied forces" in the truss.

We shall first consider the truss to be a girder of uniform cross-section through its whole length, and afterwards take into account such modifications as appear necessary in applying the theory to a truss whose chords are of a variable cross-section.

Fig. 1.



In Fig. 1 is an exaggerated representation of the curvatures which the girder assumes under the action of a force P, when it is anchored to the piers A, O and B, which are immovably fixed in the same horizontal line.

Suppose that compression be considered positive and tension negative, then from the Fig. a conception may be obtained as to which of these is brought into play at different points along the upper and lower chords.

Particularly, it is necessary to notice the plane of contraflexure, C, where the moment of flexure and the horizontal strains in each fibre change sign and are therefore zero. Through C, vertical strains only, can be propagated, for vertical strains only, have no horizontal component.

Were the position of C known, to begin with, our work would thereby be greatly simplified, for it would only be necessary to find, from the principle of the lever, how much of P rests upon A, and how much hangs at C; but now we are obliged to find first the thrust up at A and B, and from that the position of C.

Let O be the origin.

x = distance from O of any cross-section of the girder by a vertical plane.
y = depression of any point in the cross-section caused by the weight.
x' = distance from O of the point of application of P.
x_c = distance from O of the plane of contraflexure.
l = length of one span.
M_x = moment of flexure at distance x.
M_o = moment of flexure at origin.
$M_c = 0$ = moment of flexure at distance x_c.

A moment of flexure by which the girder is made to have centre of curvature below the girder will be considered positive; but when the centre is above, the moment will be negative.

Let us for brevity assume as proved, the relation given by Weisbach and other writers on the resistance of materials, viz.:

$$M_x = EI\frac{d^2y}{dx^2} = \Sigma\,[P\,(x'-x)]. \qquad (1)$$

the middle member of which is the resistance which a girder opposes to flexure, and the last member is the moment about the middle point of any cross-section whose distance from O is x, of all the forces applied to the girder between that point and its free end. For wrought iron E has been shown by experiment to be from 10,000 to 15,000 tons.

In any truss

Let $I =$ sum of the moments of inertia of the two chords about the neutral axis of the truss.

Let $I^1 =$ moment of inertia of upper chord,
and $I_1 =$ " " lower "
about the neutral axis of the girder.
$I'_g =$ moment of inertia of upper chorrd,
$I_{g\prime} =$ " " lower "
about their centres of gravity.
$a', a_1 =$ area of cross-section of metal in the chords.
$d =$ depth of truss.
$d^1 =$ depth of rectangular cross-section of either chord.

$$I = I^1 + I_1 .$$

By Weisbach,

$$I^1 = I'_g + \frac{a'd^2}{4} = \frac{a'}{4}\left(\frac{1}{3}\, d'^2 + d^2\right).$$

But $d^1 = 0$ practically by reason of the flexible joints of the chords.

$$\therefore\ I = I^1 + I_1 = \frac{d^2}{4}\,(a' + a_1).$$

From this value of I it is evident that in a truss we must consider the effect of the variable cross-section of the chords in the different parts of the bridge. This we shall do after considering the case of the girder in which I is constant. But aside from the consideration of I, it is to be noticed that Eq. (1) applies with much greater accuracy to the case of a truss, than to that of an ordinary girder, for, first, all considerations respecting longitudinal shearing strain are at once disposed of by its flexible joints, and, second, the piers may be considered immovable, which the supports of a girder usually are not.

Eq. (1) is the general second differential equation of the elastic curve, from which by integration the curve belonging to any particular forces may be obtained.

I. Let us investigate the case represented in Fig. 1, of a single force P, positive down. Let the thrust up of the piers A, O and B, be V_1, V_2, and V_3 respectively, and positive up.

From equation (1), we have when x falls in A D, for the curve A D

$$M_x = EI\,\frac{d^2y}{dx^2} = -V_1\,(l-x) \quad . \quad . \quad . \quad (2_1)^*$$

For the curve O D,

$$M_x = EI\,\frac{d^2y}{dx^2} = P\,(x'-x) - V_1\,(l-x) \quad . \quad (3_2)$$

For the curve O B,

$$M_x = EI\,\frac{d^2y}{dx^2} = V_3\,(l+x) \quad . \quad . \quad . \quad (4_3)$$

From equation (4_3) by integration,

$$EI\,\frac{dy}{dx} = V_3\left[lx + \frac{x^2}{2}\right] + C.$$

If $x = 0 \quad C = EI\,\dfrac{dy_0}{dx_0}.$

Let $t_0 = \dfrac{dy_0}{dx_0} =$ tangent of inclination of the curve at O to the axis of x

$$\therefore\ EI\left[\frac{dy}{dx} - t_0\right] = V_3\left[lx + \frac{x^2}{2}\right] \quad . \quad (5_3)$$

Similarly integrate equation (3_2).

$$\therefore\ EI\left[\frac{dy}{dx} - t_0\right] = P\left[x'x - \frac{x^2}{2}\right] - V_1\left[lx - \frac{x^2}{2}\right] \quad . \quad (6_2)$$

Integrate equation (2_1).

$$\therefore\ EI\,\frac{dy}{dx} = -V_1\left[lx - \frac{x^2}{2}\right] + C.$$

If $x = x', \quad C = EI\,\dfrac{dy'}{dx'}.$

Let $\dfrac{dy'}{dx'} = t' =$ tangent of the inclination of the curve at D, to the axis of x.

$$\therefore\ EI\left[\frac{dy}{dx} - t'\right] = -V_1\left[l\,(x - x_1) - \frac{(x^2 - x'^2)}{2}\right] \quad . \quad (7_1)$$

In equation (6_2) let $x = x'$ and (6_2) becomes

$$EI\,[t' - t_0] = P\,\frac{x'^2}{2} - V_1\left[lx' - \frac{x'^2}{2}\right].$$

Add this eq. to eq. (7_1)

$$\therefore\ EI\left[\frac{dy}{dx} - t_0\right] = P\frac{x'^2}{2} - V_1\left[lx - \frac{x^2}{2}\right]. \quad (8_1)$$

Again integrate (5_3)

$$\therefore\ EI\,[y - t_0x] = V_3\left[\frac{lx^2}{2} + \frac{x^3}{2.3}\right] \quad . \quad (9_3)$$

When $x = 0$ then $y = 0$ $\therefore$ no constant is to be added.

Integrate (6_2)

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* We shall, for convenience, call A D curve 1, O D curve 2, and O B curve 3, and show which curve any equation refers to by a subscript numeral.

$$\therefore \text{EI}\,[y - t_0 x] = \text{P}\left[\frac{x'x^2}{2} - \frac{x^3}{2.3}\right]$$

$$- \text{V}_1 \left[\frac{lx^2}{2} - \frac{x^3}{2.3}\right] . \quad . \quad (10_2)$$

Integrate (8_1) from $x = x'$ to $x = x$.

$$\therefore \text{EI}\,[y - y' - t_0\,(x - x')] = \text{P}x'^2\,\frac{(x - x')}{2}$$

$$- \text{V}_1 \left[l\frac{(x^2 - x'^2)}{2} - \frac{(x^3 - x'^3)}{2.3}\right] . \quad (11_1)$$

In eq. (10_2) let $x = x'$ then $y = y'$

$$\therefore \text{EI}\,[y' - t_0 x'] = \text{P}\left[\frac{x'^3}{2} - \frac{x'^3}{2.3}\right]$$

$$- \text{V}_1 \left[\frac{lx'^2}{2} - \frac{x'^3}{2.3}\right].$$

Add this to (11_1)

$$\therefore \text{EI}\,[y - t_0 x] = \text{P}\left[\frac{x'^2\,x}{2} - \frac{x'^3}{2.3}\right]$$

$$- \text{V}_1 \left[\frac{lx^2}{2} - \frac{x^3}{2.3}\right] \quad . \quad . \quad (12_1)$$

In (9_3) let $x = -\,l$ then $y = 0$

$$\therefore \text{EI}\,t_0 l = \frac{\text{V}_3 l^3}{3} \quad . \quad . \quad (13_3)$$

In (12_1) let $x = l$ then $y = 0$

$$\therefore -\,\text{EI}\,t_0 l = \text{P}\left[\frac{lx'^2}{2} - \frac{x'^3}{2.3}\right] - \frac{\text{V}_1 l^3}{3} \quad (14_1)$$

Add (13_3) and (14_1), then transpose, etc.,

$$\therefore 2l^3\,(\text{V}_1 - \text{V}_3) = \text{P}\,(3lx'^2 - x'^3) \quad . \quad (15)$$

Had A, O and B not been on the same horizontal line on making $x = 0$ we should have introduced proper values of y.

In eqs. (3_2) and (4_3) let $x = 0$

$$\therefore \text{M}_0 = \text{P}x' - \text{V}_1 l$$

and $$\text{M}_0 = \text{V}_3 l$$

$$\therefore 2l^3\,(\text{V}_1 + \text{V}_3) = 2\text{P}l^2x' \quad . \quad . \quad (16)$$

From eqs. (15) and (16)

$$\therefore \text{V}_1 = \frac{\text{P}x'}{4l^3}\,[2l^2 + 3lx' - x'^2] \quad . \quad . \quad (17)$$

and $$\text{V}_3 = \frac{\text{P}x'}{4l^3}\,[2l^2 - 3lx' + x'^2] \quad . \quad . \quad (18)$$

$$\text{V}_1 + \text{V}_2 + \text{V}_3 = \text{P} \quad \therefore \text{V}_2 = \text{P} - (\text{V}_1 + \text{V}_3)$$

$$\therefore \text{from (16)},\ \text{V}_2 = \text{P}\,\frac{(l - x')}{l} \quad . \quad . \quad (19)$$

To find the point of contraflexure C, from (3_2)

Put $\text{M}_c = \text{P}\,(x' - x_c) - \text{V}_1\,(l - x_c) = 0.$

Substitute in this the value of V_1 from (17)

$$\therefore x_c = \frac{(x'^2 - 3lx' + 2l^2)\,lx'}{x'^3 - 3lx'^2 - 2l^2x' + 4l^3}$$

Cancel the factor $x' - l$

$$\therefore x_c = \frac{(x' - 2l)\,lx'}{x'^2 - 2lx' - 4l^2} \quad . \quad (20_2)$$

$$\therefore x_c < \frac{1}{5}\,l.$$

SUMMARY.

For curve 1.

$$\text{EI}\,\frac{d^2y}{dx^2} = -\,\text{V}_1\,(l - x) \quad . \quad . \quad (a_1)$$

$$\text{EI}\left[\frac{dy}{dx} - t_0\right] = \text{P}\,\frac{x'^2}{2} - \text{V}_1\left[lx - \frac{x^2}{2}\right] . \ (b_1)$$

$$\text{EI}\,[y - t_0 x] = \text{P}\left[\frac{x'^2 x}{2} - \frac{x'^3}{2.3}\right]$$

$$- \text{V}_1\left[\frac{lx^2}{2} - \frac{x^3}{2.3}\right] \quad . \quad . \quad (c_1)$$

For curve 2.

$$\text{EI}\,\frac{d^2y}{dx^2} = \text{P}\,(x' - x) - \text{V}_1\,(l - x) \ . \ (a_2)$$

$$\text{EI}\left[\frac{dy}{dx} - t_0\right] = \text{P}\left[x'x - \frac{x^2}{2}\right] \quad .$$

$$- \text{V}_1\left[lx - \frac{x^2}{2}\right] \quad . \quad . \quad . \quad (b_2)$$

$$\text{EI}\,[y - t_0 x] = \text{P}\left[\frac{x'x^2}{2} - \frac{x^3}{2.3}\right]$$

$$- \text{V}_1\left[\frac{lx^2}{2} - \frac{x^3}{2.3}\right] \quad . \quad . \quad (c_2)$$

For curve 3.

$$\text{EI}\,\frac{d^2y}{dx^2} = \text{V}_3\,(l + x) \quad . \quad . \quad (a_3)$$

$$\text{EI}\left[\frac{dy}{dx} - t_0\right] = \text{V}_3\left[lx + \frac{x^2}{2}\right] . \quad . \quad (b_3)$$

$$\text{EI}\,[y - t_0 x] = \text{V}_3\left[\frac{lx^2}{2} + \frac{x^3}{2\ 3}\right] \quad . \quad (c_3)$$

$$x_c = \frac{(x' - 2l)\,l\,x'}{x'^2 - 2lx' - 4l_2} \quad . \quad (d_2)$$

If the values of V_1 and V_3 in (17) and (18) be substituted in the eqs. (a), (b) and (c), they then become definite, and we are then able to compute at any point, first, its moment of flexure, by eqs. (a), secondly its angular deflection by eqs. (b) and (14_2), and thirdly from (c) the actual deflections.

Suppose that $t_0 = 0$ (since an extended bearing on the centre pier has a tendency to effect that result).

Then in (c_1) if $x = l$, $y = 0$

$$\therefore \text{V}_1 = \text{P}x'^2\,\frac{(3l - x')}{2l^3} \quad . \quad 21$$

Substitute this V_1 in (a_2), and let $\text{M} = 0$, to find the point of contraflexure

$$\therefore x_c = \frac{x'^2 - 3lx' + 2l^2}{x'^3 - 3lx'^2 + 2l^3}\,l\,x'.$$

Cancel the factor $x' - l$.

$$\therefore x_c = \frac{(x' - 2l)\,lx'}{x'^2 - 2lx' - 2l^2} \quad . \quad (d'_3)$$

$$\therefore x_c < \frac{1}{3}\,l.$$

The integrations can be performed, and the results reached in the same manner, if the number of the weights be increased, as would be the case in a truss where the dead load is considered to be applied in equal amounts at each joint, and the live load is applied at part of the joints.

II. But for the sake of simplicity, continuing the consideration of the girder, let us investigate the case in which it is loaded uniformly through part of its length.

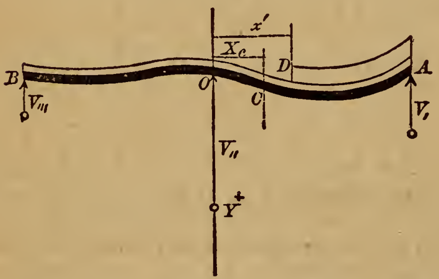
Let q = weight per unit of length of the dead load uniformly distributed along the entire girder,

and p = weight per unit of length of the line load uniformly distributed along part of the girder.

x_1 = the distance of the end of this live load from O.

In a truss, q is the bridge weight per linear unit, which may be taken as about one ton per ft., while p is the weight of a train of engines per linear unit, and may be assumed to be two tons per ft.

FIG. 2.



From the application of eq. (1) to this case, by processes precisely like those previously used, we obtain the following results:

Summary.

For curve 1.

$$\text{EI}\,\frac{d^2y}{dx^2} = \frac{1}{2}(p+q)(l-x)^2 - \text{V}_1(l-x) \quad . \quad (h_1)$$

$$\text{EI}\left[\frac{dy}{dx} - t_0\right] = \frac{1}{2}(p+q)\left[l^2x - lx^2 + \frac{x^3}{3}\right] - \frac{px_1^{\,3}}{2.3} - \text{V}_1\left[lx - \frac{x^2}{2}\right] \quad . \quad (k_1)$$

$$\text{EI}\,[y - t_0x] = \frac{1}{2}(p+q)\left[\frac{l^2x^2}{2} - \frac{lx^3}{3} + \frac{x^4}{3\ 4}\right] - \frac{px_1^{\,3}}{2.3}\left[x - \frac{x_1}{4}\right] - \text{V}_1\left[\frac{lx^2}{2} - \frac{x^3}{2.3}\right] \quad . \quad (l_1)$$

For curve 2.

$$\text{EI}\,\frac{d^2y}{dx^2} = p(l-x_1)\left[\frac{l+x_1}{2} - x\right] + \frac{1}{2}q(l-x)^2 - \text{V}_1(l-x) \quad . \quad (h_2)$$

$$\text{EI}\left[\frac{dy}{dx} - t_0\right] = \frac{p}{2}\left[(l^2 - x_1^{\,2})x - (l - x_1)x^2\right] + \frac{q}{2}\left[l^2x - lx^2 + \frac{x^3}{3}\right] - \text{V}_1\left[lx + \frac{x^2}{2}\right] \quad . \quad (k^2)$$

$$\text{EI}\,[y - t_0x] = \frac{p}{2}\left[(l^2 - x_1^{\,2})\frac{x^2}{2} - (l - x_1)\frac{x^3}{3}\right] + \frac{q}{2}\left[\frac{l^2x^2}{2} - \frac{lx^3}{3} + \frac{x^4}{3.4}\right] - \text{V}_1\left[\frac{lx^2}{2} + \frac{x^3}{2.3}\right] . \quad (l_2)$$

For curve 3.

$$\text{EI}\,\frac{d^2y}{dx^2} = \frac{q}{2}(l+x)^2 - \text{V}_3(l+x) \quad . \quad (h_3)$$

$$\text{EI}\left[\frac{dy}{dx} - t_0\right] = \frac{q}{2}\left[l^2x + lx_2 + \frac{x^2}{3}\right] - \text{V}_3\left[lx + \frac{x^2}{2}\right] \quad . \quad . \quad (k_3)$$

$$\text{EI}\,[y - t_0x] = \frac{q}{2}\left[\frac{l^2x^2}{2} + \frac{lx^3}{3} + \frac{x^4}{3.4}\right] - \text{V}_3\left[\frac{lx^2}{2} + \frac{x^3}{2.3}\right] \quad . \quad . \quad (l_3)$$

To obtain t_0, let $x = l$ in eq. (l_2), then will $y = 0$.

$$\therefore -\text{EI}\,t_0\,l = \frac{1}{8}(p+q)\,l^4 - \frac{p\,x_1^{\,3}}{2.3}\left[l - \frac{x_2}{4}\right] - \text{V}_1\,\frac{l^3}{3} \quad . \quad . \quad . \quad (l_1)$$

$$\text{V}_1 = \frac{p\,(x_1^{\,4} - 4lx_1^{\,3} - 4l^2x_1^{\,2} + 7l^4) + 6ql^4}{16l^3} \quad . \quad (g)$$

$$\text{V}_3 = \frac{p\,(x_1^{\,4} - 4lx_1^{\,3} + 4l^2x_1^{\,2} - l^4) + 6ql^4}{16l^3} \quad . \quad (j)$$

$$\text{V}_1 + \text{V}_2 + \text{V}_3 = p\,(l - x_1) + 2ql$$

$$\therefore \text{V}_2 = \frac{p\,(-x_1^{\,4} + 4lx_1^{\,3} - 8l^3x_1 + 5l^4) + 10ql^4}{8l^3} . \quad (i)$$

Put $(h_1) = 0$, cancel the factor $(l - x)$ and eliminate V_1 by (g)

$$\therefore x_c = \frac{p\,(-x_1^{\,4} + 4lx_1^{\,3} + 4l^2x_1^{\,2} + l^4) + 2ql^4}{8\,(p+q)\,l^3} \quad (e_1)$$

From (e_1) we find the position of C when the live load extends upon the girder sufficiently far to cover C. When the end of the load first reaches to C can be determined by making $x_c = x_1$ in (e_1).

If $x_1 = 0$

$$x_c = \left(\frac{p+2q}{p+q}\right)\frac{l}{8} = \left(1+\frac{q}{p+q}\right)\frac{l}{8}$$

If also

$$p=0 \quad \therefore x_c = \frac{l}{4}$$

$$p=q \quad \therefore x_c = \frac{3l}{16}$$

$$p=2q \quad \therefore x_c = \frac{l}{6}$$

$$p=3q \quad \therefore x_c = \frac{5l}{32}$$

etc., etc.

Similarly put $(h_2)=0$, eliminate V_1 and in case of $q=0$ we can readily find x_c. Then cancel the factor $(l-x_1)$

$$\therefore x_c = \frac{x_1^2 - 2lx_1 - l^2}{x_1^2 - 2lx_1 - 9l^2}.l \quad \therefore x_c < \frac{l}{5},$$

which result agrees with (20_2). Also put $(l_1)=0$, cancel the factor $(l=x)$ and eliminate V_3 by (j)

$$\therefore x_c = \frac{p(x_1^4 - 4lx_1^3 + 4l^2x_1^2 - l^4) - 2ql^4}{8ql^3} \qquad (e_3)$$

From (e_3) we find the position of C in curve 3 when the live load extends upon the girder from A to any distance towards O.

$$\text{If } x_1 = 0 \quad \therefore x_c = -\left(2+\frac{p}{q}\right)\frac{l}{8}.$$

If also $p=0$ $\quad x_c = -\frac{l}{4}$

" " $p=q$ $\quad x_c = -\frac{3l}{8}$

" " $p=2q$ $\quad x_c = -\frac{l}{2}$

" " $p=3q$ $\quad x_c = -\frac{5l}{8}$

" " $p=4q$ $\quad x_c = -\frac{3l}{4}$

Had the girder been by some means kept horizontal at O, then $t_0=0$ in eqs. (k_1), (k_2), (k_3), (l_1), (l_2) and (l_3), and we should obtain

$$V_1 = \frac{p(x_1^4 - 4lx_1^3 + 3l^4) + 3ql^4}{8l^3} \quad . \qquad (g)'$$

$$V_3 = \frac{3ql}{8} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (j)'$$

$$V_2 = \frac{p(-x_1^4 + 4lx_1^3 - 8l^3x_1 + 5l^4) + 10ql^4}{8l^3} \qquad (i)'$$

If the load covers C, then put $(h_1)=0$, etc.

$$\therefore x_c = \frac{p(-x_1^4 + 4lx_1^3 + l^4) + ql^4}{4(p+q)l^3} \quad . \qquad (e_1)'$$

If $\quad x_1 = 0, \quad x_c = \frac{l}{4}.$

Again to find the effect of the live load only, let $q=0$, put $(h_2)=0$, find x_c and cancel the factor $(l-x_1)$

$$\therefore x_c = \frac{x_1^2 - 2lx_1 - l^2}{x_1^2 - 2lx_1 - 5l^2}l \quad \therefore x_c < \frac{l}{3}.$$

If $x_c = x_1$, $x_c = (2 \pm \sqrt{3})l = 0.268l$.

III. In case the live load extends from A to some point D *between* O and B of Fig. 2, the eqs. derived from eq. (1) become

SUMMARY.

For curve 1, *i. e.* O A,

$$EI\frac{d^2y}{dx^2} = \frac{1}{2}(p+q)(l-x)^2 - V_1(l-x) \,. \quad (m_1)$$

$$EI\left[\frac{dy}{dx} - t_0x\right] = \frac{1}{2}(p+q)\left[l^2x - lx^2 + \frac{x^3}{3}\right]$$
$$- V_1\left[lx - \frac{x^2}{2}\right] . \quad . \quad . \quad (n_1)$$

$$EI[y - t_0x] = \frac{1}{2}(p+q)\left[\frac{l^2x^2}{2} - \frac{lx^3}{3} + \frac{x^4}{3.4}\right]$$
$$- V_1\left[\frac{lx^2}{2} - \frac{x^3}{2.3}\right] \quad . \quad . \quad (o_1)$$

For curve 2, *i. e.*, O D,

$$EI\frac{d^2y}{dx^2} = \frac{p}{2}(x-x_1)^2 + \frac{q}{2}(l+x)^2$$
$$- V_3(l+x) \quad . \quad . \quad (m_2)$$

$$EI\left[\frac{dy}{dx} - t_0\right] = \frac{p}{2}\left[\frac{x^3}{3} - x_1x + x_1^2x\right]$$
$$+ \frac{q}{2}\left[l^2x + lx^2 + \frac{x^3}{3}\right] - V_3\left[lx + \frac{x^2}{2}\right] \cdot (n_2)$$

$$EI[y - t_0x] = \frac{p}{2}\left[\frac{x^4}{3.4} - \frac{x_1x^3}{3} + \frac{x_1^2x^2}{2}\right]$$
$$+ \frac{q}{2}\left[\frac{l^2x^2}{2} + \frac{lx^3}{3} + \frac{x^4}{3.4}\right] - V_3\left[\frac{lx^2}{2} + \frac{x^3}{2.3}\right] \cdot (o_2)$$

For curve 3, *i. e.*, D B.

$$EI\frac{d^2y}{dx_2} = \frac{q}{2}(l+x)^2 - V_3(l+x) \quad . \quad (m_3)$$

$$EI\left[\frac{dy}{dx} - t_0\right] = \frac{px_1^3}{2.3} + \frac{q}{2}\left[l^2x + lx^2 + \frac{x^3}{3}\right]$$
$$- V_3\left[lx + \frac{x^2}{2}\right] . \quad . \quad (n_3)$$

$$EI[y - t_0x] = \frac{px_1^3}{2.3}\left[x - \frac{x_1}{4}\right]$$
$$+ \frac{q}{2}\left[\frac{l^2x^2}{2} + \frac{lx^3}{3} + \frac{x^4}{3.4}\right] - V_3\left[\frac{lx^2}{2} + \frac{x^3}{2.3}\right] . \ (o_3)$$

To obtain t_0, let $x = l$ in eq. (o_1). then $y = 0$.

$$\therefore EIt_0l = \frac{1}{8}(p+q)l_4 - V_1\frac{l^3}{3} \quad . \quad (n_1)'.$$

$$\therefore\ \mathrm{V}_1 = \frac{p\,(-x_1{}^4-4lx_1{}^3-4l^2x_1{}^2+7l^4)+6ql^4}{16\,l^3}$$

$$\mathrm{V}_3 = \frac{p\,(-x_1{}^4-4lx_1{}^3+4l^2x_1{}^2-l^4)+6ql^4}{16\,l^3}$$

$$\mathrm{V}_2 = \frac{p\,(x_1{}^4+4lx_1{}^3-8l^3x_1+5l^4)+10ql^4}{8\,l^3}.$$

From (m_1)

$$x_c = \frac{p\ x_1{}^4+4lx_1{}^3+4l^2x_1{}^2+l^4)+2ql^4}{8\,(p+q)\,l^3} \qquad (f_1)$$

From (m_3)

$$x_c = \frac{p\,(-x_1{}^4-4lx_1{}^3+4l^2x_1{}^2-l^4)-2ql^4}{8\,ql^3} \qquad (f_3)$$

If $\quad x_1 = 0 \qquad x_c = -\left(2+\frac{p}{q}\right)\frac{l}{8}$,

which measures the greatest excursion of the point C from O; compare (e_3). C must never be within $\frac{1}{4}\,l$ of the end B, lest some sudden impact of the moving load lift that end from the piers.

IV. Let us now consider the case of a truss whose chords are proportioned to the strain brought to bear upon them when the live load extends its entire length, *i. e.*,

$$\mathrm{I}_x \propto \mathrm{M}_x \text{ and } t_0 = 0.$$

For curve 2, if c is some constant,

$$\therefore\ \frac{d^2y}{dx^2} = \frac{\mathrm{M}_x}{\mathrm{E\,I}_x} = c \quad . \quad . \quad (r_2)$$

$$\frac{dy}{dx} = cx \quad . \quad . \quad . \quad . \quad (s_2)$$

$$y = \frac{cx^2}{2} \quad . \quad . \quad . \quad . \quad (t_2)$$

For curve 1.

$$\frac{d^2y}{dx^2} = -\frac{\mathrm{M}_x}{\mathrm{E\,I}_x} = -c \quad . \quad (r_1)$$

$$\frac{dy}{dx} = -cx + 2cx_c \quad . \quad . \quad (s_1)$$

$$y = 2cx_cx - \frac{cx^2}{2} - cx_c{}^2 \quad . \quad (t_1)$$

If $x = l$ then $y = 0$.

$$\therefore\ x_c - 2\,lx_c = -\frac{l^2}{2}$$

$$\therefore\ x_c = \left(1 \pm \frac{1}{2}\sqrt{2}\right)l = 0.293\,l.$$

Eqs. (t_1) and (t_2) represent parabolas having a common tangent at C. It is evident that if the chords were exactly proportioned to the strain they are subjected to, the curvature would at each point be uniform, *i. e.*, the curves would be arcs of equal circles, and in case the depression is small $x_c = \frac{1}{3}\,l$ nearly.

The results of these investigations may be stated thus:

1*st.* A drawbridge of two equal spans when uniformly loaded never has its points of contraflexure at a distance greater than $\frac{1}{3}\,l$ from its centre, provided the piers are at the same level, and the drawbridge straight.

The conditions of this proviso are readily fulfilled in this way, viz.: the bearings on the end piers may be raised or lowered to such an extent as to cause the truss to exert on these bearings the computed pressure obtained from (g) and (j) when $p = o$.

The mutual relation of x_c and V_1 when $p = 0$ may be shown thus by the principle of the lever.

If	$x_c = l$	then	$\mathrm{V}_1 = 0$,
"	$x_c = \frac{9\,l}{12}$	"	$\mathrm{V}_1 = \frac{3\,ql}{24}$,
"	$x_c = \frac{8\,l}{12}$	"	$\mathrm{V}_1 = \frac{4\,ql}{24}$,
"	$x_c = \frac{6l}{12}$	"	$\mathrm{V}_1 = \frac{6\,ql}{24}$,
"	$x_c = \frac{4\,l}{12}$	"	$\mathrm{V}_1 = \frac{8\,ql}{24}$,
"	$x_c = \frac{3\,l}{12}$	"	$\mathrm{V}_1 = \frac{9\,ql}{24}$,
"	$x_c = \frac{2\,l}{12}$	"	$\mathrm{V}_1 = \frac{10\,ql}{24}$,
	etc.,	etc.,	etc.

2*d.* A truss so supported never, under any distribution of a partial uniform load, has a point of contraflexure at a distance greater than $\frac{2}{3}\,l$ from its centre.

3*d.* If the draw is swung from its end piers, the entire upper chord undergoes tension, the lower compression, and the moment of flexure at O is

$$\mathrm{M}_0 = \frac{ql^2}{2}.$$

When the draw is supported on three piers and loaded throughout, the moment at O is as large as is possible under a load, and is, if we take $x_c = \frac{1}{3}\,l$,

$$\mathrm{M'}_0 = \frac{1}{3}\,(p+q)\,l\,.\,\frac{l}{3} + \frac{1}{3}\,(p+q)\,l\,.\,\frac{l}{6}$$

$$\therefore\ \mathrm{M'}_0 = \frac{1}{6}\,(p+q)\,l^2.$$

Now if

$$p = 2q \qquad M'_0 = \frac{ql^2}{6}.$$

Hence if the truss is of sufficient strength to swing, the centre third of it is sufficiently strong to sustain a uniform live load of twice the weight of the truss.

4*th.* The point of contraflexure may approach the centre O, so that $x_c = \frac{1}{6} l$.

RECENT IMPROVEMENTS IN STEAM BOILERS.*

From the "English Mechanic and World of Science."

When I read a paper before this Society two years ago I endeavored to give the members present on that occasion an account of a cast-iron boiler, which had been brought out originally in the United States, and subsequently introduced to a considerable extent in this country. One of the advantages of this boiler over those of the Cornish and Lancashire type is, as I pointed out, a rapid circulation of the water. To obtain this essential feature of improved steam production has been a chief object in all the recent improvements in steam-generation I have to describe to you this evening. By recent, I may here state, I mean within the last ten or twelve years.

As you are aware, the Cornish boiler is a long cylinder laid on its side, and is constructed with an internal cylindrical flue running all the length of the boiler, and fixed eccentrically to the outer shell. This flue contains the fire-grate, and is entirely surrounded by water. As the flame of the furnace and the heated gases have not yielded up nearly all their caloric on reaching the back end of this internal flue, other flues are formed in the brickwork setting of the boiler. The fire itself is within the boiler, and the heat is brought into further contact with the water to be raised into steam, by the products of combustion being led along the external flues to the chimney. It is evident that a certain portion of the heat thus supplied and conducted through flues, formed to a great extent of brickwork, must be absorbed by that brickwork, and, from the fact of the flues being external, only a portion of the heat passing along them can be effective in raising the water into steam. From the nature and arrangement of this type of boiler slow combustion is the only means by which it can be worked economically. The heat could not be absorbed by the water with sufficient rapidity to render quick combustion economical; because, in addition to the increased caloric which would be thus absorbed by the brickwork of the flues, there is a large inert mass of water to be raised into steam. That a fair percentage of the heat may be utilized sufficient time must be allowed, otherwise a certain proportion of heat must pass off by the chimney, as the circulation of the water is sluggish. If, however, means are devised by which the water to be raised into steam can be brought more quickly into contact with the fire and products therefrom, a more rapid combustion can be employed with at least equal economy. If, again, an equal quantity of steam can be raised in the same time by a much smaller boiler, and at—say—even the same expenditure of fuel, here is a decided gain.

To effect this, the large body of inert water, in boilers on the Cornish system, must be broken up and separated, in order that the heat may be brought, as it were, into more immediate and intimate contact with the water in smaller bodies. In doing this, care should be taken that sufficient oxygen be supplied for the support of the combustion, and, thereby, for the addition of intensity to the heat. This is the direction in which all the more recent improvements in boilers, that I know of, tend. It is important, besides, that the circulation of the water in a boiler should be in exact proportion to the heat supplied.

The first boiler I have to bring before you this evening is the "Field Boiler." In this arrangement, the heat being led by many small channels through the water, the water itself is thereby caused to pass in small streams through the hottest part of the furnace, and at a rate proportionate to the heat supplied, as the one effect is the complement of the other. Therefore, as the heat is increased or diminished, so will the speed of the circulation of the water be more or less rapid, and no waste of caloric

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[*] A paper read before the Civil and Mechanical Engineers' Society, by W. Forsyth Black.

will arise from quick combustion. This boiler consists of two principal parts, viz., the space for water and steam, and the furnace where the combustion is carried on.

For stationary engines it is made of a cylindrical form, set on end. An inner cylinder contains the furnace and the circulating tubes, and from the top centre of this the uptake leading to the chimney springs. The water surrounds this inner cylinder, and rises to a level above the tubes, and surrounds the lower part of the uptake. The tubes themselves are disposed annularly round a central flue, which leads straight up to the uptake, and to insure that, instead of directly ascending the same, the flame shall spread out round the tubes, a damper, or baffle of cast iron is suspended in this said flue, and can be raised or lowered at pleasure, for in some measure regulating the draught. The tubes, wherein most of the peculiarity of this boiler consists, are closed at the lower ends, and within each is freely suspended, by means of feathers, a smaller tube, open at both ends. The outer tubes are fixed to the tube-plate, which is the crown of the internal cylinder of the boiler above mentioned, as follows:—The holes in the tube-plate, for receiving these tubes, are made slightly conical, their smallest diameter at the lower surface of the tube-plate being equal to that of tubes externally, and taper upwards. The upper ends of the tubes having been slightly expanded, a tube is placed in position; a conical steel mandrel is then inserted in the upper end of the tube, and one or two blows of a hammer are struck on this mandrel to further extend the tube, and to insure it being jammed into the hole in the tube plate. From the modus operandi it is evident that a new tube can at any time be readily fitted should one be injured, and that no specially skilled workman is required for this purpose. The outer tubes are of wrought iron, and are from 2 to 3 in. outside diameter, and from one-eighth to three-sixteenths of an inch in thickness. The inner tubes are of brass, from one-twelfth to one-sixteenth of an inch in thickness, and the annular space between these and the outer tubes half an inch across, which fixes diameter of these inner tubes. These have at their upper ends feathers of brass brazed on to them, by which means they are suspended in the outer tubes. These upper ends are further furnished with funnel-shaped mouths brazed on to them, which serve as deflectors to guide and accelerate the circulation of the water. The tubes are placed sufficiently far apart to allow the heat free access round them, and the distance between is usually not less than half a diameter of outer tubes.

When the fire has been lighted, and the heat commences to rise up round the tubes, the water in these begins to circulate. As an increment of heat is added to the water in the annular space between the outer and inner tubes, the water therein begins to ascend, and its place is supplied by cold water flowing down the inner tubes. This action goes on increasing gradually till boiling-point of the whole water is reached, when the velocity of flow is greatly increased, owing to the great difference in specific gravity of the water, mixed with steam, ascending from immediate contact with the hottest part of the fire, and of the solid water descending from above.

In the case of a boiler having 490 sq. ft. of tube surface, we have the outer tubes 2 in. in internal, and 2¼ in. in external diameter, and the inner tubes 1 in. in external diameter, leaving an annular space of half an inch all round between the tubes. Taking the flow of water down the inner tubes at 10 ft. per second, the number of tubes at 289 will give a quantity of water equal to about 80 gallons passing down the tubes, and being brought under the most intense action of the furnace. Owing to the circulation, the water passing down is from the part of the boiler where the water is less heated, and will be the more ready to absorb the heat of the fire as it approaches the hottest part of the furnace. It passes on carrying with it to the top part of the boiler its steam, which remains in the steam chest there till used by the engine, and the feed water coming up from the point of injection near bottom of boiler, passes up through the annular space, between the outer and inner cylinders of the boiler, and down through the inner tubes to the hottest point, and so the circulation goes on.

An important point to be considered with regard to boilers is incrustation; how far it goes on, and how far it is avoided. It is clear that where the circulation is rapid, as in this and kindred tubular boilers, no deposit can settle in the tubes; but must fall to bottom of boiler. From thence it is expelled periodically by the blow-off cock, and when the boiler is not at work, by means of the mud-hole it can be thoroughly cleared away.

The simplest form of this boiler, viz., the upright and cylindrical, is that employed for stationary engines. Two boilers of this description occupying a ground space of less than 90 sq. ft. have been found to do the work of two Cornish boilers covering an area of about 400 sq. ft. A boiler of this same design calculated to evaporate 25 cubic feet per hour, and nominally of 25 horse-power, was erected some years ago at a colliery in the north of England, and drove an engine having a sixteen-inch cylinder and a three-feet stroke at the rate of 50 revolutions per minute, under a pressure of 50 lbs. of steam per sq. in. This was the average performance, and from a record kept, it was found that the maximum evaporation was 26 cubic feet, and the minimum 22.6 cubic feet. The indicated horse-power of the engine was 55. The amount of coal used during 114 hours was 167 cwt., equalling 164 lbs. per hour, or very nearly 3 lbs. for each indicated horse-power. The fuel used was refuse coal from the colliery which could not be sold, and refuse from the coke ovens. In experiments made with five 60 horse-power boilers of this kind, used to work hydraulic machinery for warehousing grain, steam was got up from cold water to a pressure of 10 lbs. in 20 minutes; while in the case of Cornish boilers three-quarters of an hour would have been necessary to attain a like result. In 30 minutes there was steam of 50 lbs. pressure. Turf has also been used for fuel in boilers of this style, and with satisfactory results, owing to their excellent draught.

This boiler has also been slightly modified, and employed for utilizing the waste heat from re-heating furnaces.

To admit of a fuller advantage being taken of the hottest part of the flame by bringing it more directly on the tubes, a down draught modification has been made by Mr. Field in conjunction with Mr. Lloyd Wise. This consists in placing the chimney at the side of, and at a little way away from the boiler, and in filling up with additional tubes the central flue of the arrangement I have described. Inside the fire-box, at a little distance from the cylindrical wall of it, and opposite the furnace door, is fixed a cast-iron diaphragm, which is protected from the heat of the flames by a lining of fire-clay. This diaphragm extends to within a suitable distance of the tube plates, and the smoke and gases pass over it, through the space left, then down between it and wall of inner cylinder, and onwards by flue in brickwork setting of boiler to the chimney. The top of this boiler is flat, and is stayed to the tube plate.

Boilers of this arrangement have given satisfactory results. One has been for some time in constant use at the Victoria Works, Coal Yard, London. There repeated competitive trials have been made between this and a Cornish boiler. The latter is covered in with brickwork, is well set, and has a good draught. It was clean, and consumed 4 tons of coals, at 20 shillings per ton, in 16½ hours, which gives eightpence halfpenny per hour; whereas the former boiler, in 60 hours, consumed 2 chaldrons of coke at 16 shillings per chaldron, which gives fivepence halfpenny per hour, or a saving of over 30 per cent. Both boilers performed exactly the same work during their respective trials. Field tubes have also been fixed to Cornish, and in double-flued boilers, and have been the means of a great saving of fuel. Beginning a short distance from the bridge, the tubes are fixed in the method already explained by drifting, and are arranged, in 2 or 3 rows, according to size of boiler, continuously to the front end of the boiler. This is accomplished from the inside of the boiler, and, consequently, nothing has to be disturbed. In addition to the fuel being economized, an increase of steaming power is acquired. It has been found from practice that not only are the tubes themselves free from scale, but also that no sediment lodges on the plates into which the tubes are fixed, whereas previous to this addition a thick layer of scale accumulated on this part of the boiler. This is due to the activity of the circulation of the water. To test comparatively the effect of such an application of tubes to Cornish boilers, a thorough trial was made for a considerable time, as regards both evaporation of water and economy of fuel. Both boilers (*i. e.*, the one furnished with tubes, and the other an ordinary Cornish boiler) were exactly of the same size, had one chimney, and were worked under conditions precisely similar. The size of each boiler was 25 ft. 6 in. long, and 6 ft. in diameter, and each had an internal flue 3 ft in diameter. One was furnished with 36 tubes, which was only about one-quarter of the number that might have been employed with advantage. The result was fully 12 per cent. of a saving of fuel in favor of the tubed boiler.

The following is the report of an experiment by the engineer of some extensive mills in the north of England, in conducting which a water-meter was used:—

"Boiler 28 ft. long and 6 ft. diameter, having two flues 2 ft. diameter, half-inch plates, fire-grate 2 ft. wide and 4 ft. long; coal burned, 1 ton 18 cwt = 4,256 lbs.; water evaporated, 2,225 gallons=22,250 lbs., which gives 5.23 lbs. water evaporated per 1 lb. of coal."

"Boiler 28 ft. long and 7 ft. diameter, having two flues 2 ft. 9 in. diameter, half-inch plates, fitted with 45 'Field tubes' 12 in. long in each flue. Coal burned, 3 tons 12 cwt. = 8,064 lbs.; water evaporated, 6,287 gallons = 62,870 lbs., which gives 7.8 lbs. of water evaporated per 1 lb. of coal."

This gentleman adds: "Very bad coals were used throughout; but the experiment shows a great advantage in the use of Field tubes."

These boilers, upright and cylindrical in form, have been employed for steam launches, and boilers of this type, and of this or other internal arrangements, commend themselves very obviously for such service on account of the great saving of space, which in this case is specially of much moment. Two boilers of the same type were fitted to a fine lake steamer, the Schwyze, launched on Lake Constance by a Swiss firm of engineers. The boat is 130 ft. long, 16 ft. beam, and draws 2 ft. 8 in. of water. She is fitted with a pair of inclined direct-acting condensing engines, 17 in. cylinder, 2 ft. 8 in. stroke. The steam is worked expansively, being cut off at one-tenth of the stroke. Her boilers are 4 ft. 10 in. in diameter, and expose 600 ft. of heating surface. With steam at 60 lbs. pressure 150 indicated horse-power is obtained from the engines with 140 kilogrammes=310 lbs. of Saarbrück coal per hour, and with this the speed of the boat is equal to 12 statute miles per hour. This is the average speed; but considerably higher results have been obtained by forcing the fires. The height of the boilers is limited below what would have been desirable, in consequence of the shallow draught of the boat, and from the fact that she has to pass under the bridge at Constance, and on this account the economy of fuel is not greater.

On the Continent, and more especially in Germany, the "Field" system is extensively used, and lately, I understand, Mr. Krupp, of Essen, was applying for quotations for boilers on this plan, of a collective power of 1,000 horses, several of which were to be individually of 100 horse-power.

Mr. Alexander Chaplin's arrangement of tubular vertical boilers is his improvement in this direction on the vertical dome boiler of the simplest form, which he introduced ten years previous to what I am now about to describe. I may mention in passing, that this consisted of an outer and inner cylinder, with the addition for larger sizes, from 13 horse-power upwards, of 1 or 2 cross tubes in upper part of internal cylinder, which forms the fire-box. On the top of this, which is of a dome shape, sediment cannot lodge; but falls into the water space below the level of the fire-grate, from which it is easily removed by the blow-off cock at regular intervals, according to the quality of the water used for feed, and by taking off the mud hole door when boiler is not at work. The crown of fire-box is so far removed from the fire-grate that it is not liable to be acted on injuriously by the heat. Between outer and inner cylinder there is an annular cooler space surrounding the fire-box, above the top of which there is ample water, and especially steam space. The uptake which leads from furnace crown to funnel, or chimney, at top of the boiler is tapered to increase the draught, and serves, in addition, the purpose of a very efficient and strong stay. The large area of the fire-grate, with the high fire-box, serves to burn up the cheaper kinds of fuel; coal dross, wood, peat, refuse of sugar cane, and such cheap and refractory fuel, by the addition of a forced combustion and smoke-burning apparatus, can be profitably employed.

The cross tubes I have mentioned above are from 6 to 12 in. in diameter, and are placed across upper part of the fire-box, at an angle, to prevent sediment lodging within them. When two are employed, they are placed at right angles, and one above the other.

By the addition of hanging tubes to his simple dome and internal fire-box boiler I have just described, and by so superseding the employment of cross tubes for larger sizes, Mr. Chaplin has produced his tubular boiler, which he introduced in 1865. The tubes, which are closed at their lower ends, descend from the crown of the fire-box, which thus forms the tube-plate. The tubes are screwed at their upper ends, and secured in the tube-plate, in which holes, furnished with screw threads, are made to receive the tubes. The section of the tube-plate is curved, and as the holes for the tubes are bored at right angles to direction of curve, the tubes when placed in position converge towards each other at their lower ends, which nearly approximate.

As in the former case, the uptake flue leading straight to the chimney, stretches upward from the centre of dome of fire-box, and is tapered, its lower end being the narrowest part. The object in making the tubes thus converge, is to insure that the flames and heated gases shall not pass directly up the chimney, but be drawn to the sides of the fire-box in the first instance, and then across the tube to the uptake. As in the other case, the large fire-box and good draught admit of refuse, refractory coal, and fuel being burnt, and, when necessary, combustion may be assisted by such means as I have indicated. The tubes are from 2 to 3 in. in diameter; the metal is from one-eighth to three-sixteenths of an inch in thickness. As a minimum they have been fixed with the ends only 9 in. from fire-grate.

This arrangement of boiler has been used extensively for steam cranes, stationary, portable, and contractors' locomotive engines, as well as for high-pressure boat engines, and the boilers are generally worked at a pressure of 60 lbs. on the sq. in.

More recently—viz., in 1870—the same inventor introduced a system of separation applicable to all the forms of tubular boilers he has employed, as well as to others of a kindred description. In many cases, by facilitating transport, this is an improvement of much practical value. These separating boilers, then, are in two parts. The one contains the steam and top water space, and in the case of the tubular arrangement carries, in addition, the tubes.

The other contains the fire-box, and the annular water space surrounding it. For a reason that will presently appear, the upper portion is of a greater diameter than the lower. There is no difficulty about the junction of the two parts, as with a slight exception the joint at their connection is simply a smoke joint. The bottom of upper portion is also both tube plate and fire-box crown. Communication between the steam and water space in upper portion, and the annular water space surrounding fire-box in lower portion, is effected partly by means of tubular studs or bolts. If the former, these are screwed into top of annular space (which is made close at top), and, projecting through holes in bottom of upper portion, are then secured by nuts which must be screwed down in such a way that no steam will pass into smoke joint. This latter is kept tight by a joint ring of sheet lead. This by melting would allow the steam to escape, and so give warning should the water in the boiler sink too low from any neglect or other extraordinary cause.

Additional communication between the two parts of this style of boiler is obtained by outside circulating pipes, which depend vertically from the bottom and projecting part of upper portion to the lowest part of the boiler. These can also be used for removing any sediment that may lodge on outer circle of the tube plate, which in this boiler is rather beyond the action of the circulation of the tubes. The cocks at lower end of these outside pipes are so arranged that, in addition to establishing, as desired, the communications necessary for these operations, they can be used for blowing down the boiler, and for expelling the sediment which will lodge at lowest part of annular water space. Through one of these cocks also the feed water may be supplied. If a central flue be employed instead of converging tubes, it is necessary, as in former boiler, to make use of a damper or baffle, which should be arranged so that it can be raised or lowered as may be desired.

When a boiler of this kind is to be put to work, the communication by outside pipes between upper and lower water spaces is shut off by means of the cocks, and when steam begins to rise, by turning these cocks in the direction proper for that object, the said communication is established, and increased circulation results.

On account of bad health, and business engagements, the inventor has not had leisure to fully introduce this improvement; but he found that in the only boiler of this kind that had been made, and which was constructed from his own design, all his expectations were realized. This boiler was made for a river steamer.

Mr. Chaplin has had a long and extensive experience in the construction of boilers, and when the idea of making use of hanging tubes first occurred to him, he tested the operation he expected would be carried on in these tubes in the following manner:—

A small tank open at the top was made, and a tube, closed at lower end, was screwed into the bottom of this tank, and depended vertically. The tube and part of the tank were filled with water, and this experimental and fragmentary boiler was placed on a smithy fire, which was made to burn fiercely by means of the blast. Every 10 or 11 seconds a ball of steam as it were seemed to rise up to surface of the water, which, as it were, divided, to allow the steam to pass off. There was no disturbance upward of the water, and nothing at all approaching to a miniature jet of water appeared above the tube when the steam came up. This satisfied the experimenter that boilers furnished with these tubes would not prime, and that from the intense action of the first tube, no sediment would lodge in such tube, both which convictions actual practice proved subsequently to be correct. The experience of years has also proved that to whatever extent such appliances as internal tubes may assist or increase the circulation of the water, simple close-ended tubes used in these boilers establish an efficient circulation. The water in fact arranges its own currents of circulation under these circumstances. An extensive manufacture of these boilers is carried on at the present time.

The last I have to bring before you this evening is the Davy-Paxman boiler. The inventors set out from the same upright cylindrical type of boiler we have already been considering.

To bring the water into immediate and direct contact with the hottest part of the fire, these gentlemen employ tubes differing in arrangement from both the previous tubular boilers I have been endeavoring to describe to you. As in those, the tubes here, too, depend from the tube plate into holes in which their upper ends are fixed; but when they approach to within 10 or 12 ft. of the fire-grate they are bent round, and their lower ends are fixed in holes in the cylindrical wall of the fire-box. The tubes are also tapered from commencement of bend to their lower ends. The entire arrangement is shown in engraving.

There is a strong upward rush of water through the tubes, owing to the action of the fire on them when the boiler is set to work. The inventors further increase, by tapering the tubes as described, the velocity of this rush, so no sediment will be deposited elsewhere than in the bottom of the boiler, whence it is removed by blow-off cocks when the boiler is at work, or when not, through mud-holes, by taking off the mud-hole door. The tubes are kept tight by being expanded when placed in position, and "snapped." Should a new tube be required the old one is cut out; the new one is first inserted in the tube plate, through which it is projected; the lower end is then inserted in its place, and driven tight from top end. From the confined size of annular space, it is impossible to expand and snap it; so it is caulked, which is found sufficient. The top end can be easily got at for fixing by ordinary method. The makers have put in hundreds of tubes in this way, and have never heard of one failure of any so put in.

The inventors found so rapid circulation, or so violent action took place in their boiler, that, in order to prevent the serious evil of priming, they were obliged to employ a special arrangement somewhat similar in purpose to the funnel-shaped deflectors of the Field boiler. This consists of a conical valve, furnished with a flat dished cover, fixed a little above it, and this kind of deflector is inserted in top end of each tube, as shown in engraving.

When this deflector was not used, it was found that the water rushed up like a fountain from the tubes, and this fact was seen by the manhole being left without its door, and by heat only sufficient to raise the water to boiling-point being supplied. In same manner when the deflector was applied, it was seen that the rush was changed into a horizontal and downward movement of the water, the result of the cover of deflector valve intercepting the upward force of the water. The surface on water level was thus left smooth, and the danger of priming averted.

The deflectors are simply driven in tight by hammering until about a quarter of an inch of space is left between their covers and the tube plate. In the central flue there is suspended a damper, or baffle of cast iron to prevent, as in the previous cases, the too ready escape of the heated gases by the chimney. This is adjustable as to its height above the fire-grate, and can be raised or lowered by hand. These tubes, I am informed, have been applied many times to Cornish boilers, and the results are said to be a saving in fuel of from 25 to 40 per cent.

As in all boilers of this type, steam is raised very quickly in the kind we are now considering, and 60 lbs. pressure has been raised from cold water in 20 min., and the same has even been done in 17½ min.

In Messrs. Davy, Paxman & Co's factory a good Cornish boiler was replaced by one of these, and the experience of these gentlemen is that steam can be raised to 50 lbs. or 60 lbs. in 15 min., and that the amount of coal used for a day of 10 hours is very litle more than was consumed by the Cornish boiler during the morning, and that, in addition, twenty-five per cent. more work is done.

A 10 horse-power boiler was used at the International Exhibition for driving the machinery in the Scientific department, and in 13 working days the consumption of fuel was 26 cwt. of coke, and the duty done by the engine was 6 horse-power, thus making the low daily consumption of 2 cwt. of coke.

With regard to the style of tubes here employed Mr. Chaplin made use of a similar contrivance many years ago; but he kept them higher above the fire-grate at their lower ends, by which means he avoided the excessive action which here necessitates the use of deflectors. When the tubes are brought down so low as shown in the engraving, vaporization takes place low down in the tube, and the steam in its upward rush carries the water along with it from upper part of the tube. The reason Mr. Chaplin did not go on making boilers with this kind of tube was simply because he found them too expensive.

How far the various boilers will compare in price I cannot definitely say; but from the simplicity of construction, I should place Mr. Chaplin's first as to that advantage.

As regards steam raising, I should say all are about on a par; but unless some special trial were instituted as a comparative test, one can only pronounce on this point by reasoning from analogy.

All these boilers possess their essential principles in common, and all are arranged for the rapid and regulated circulation of water, its intimate contact in small bodies with the heat of the furnace, an economical employment of the same, and for the fall and deposit of sediment at the bottom of the boiler. The results from these most important features are a rapid production of steam at a small expense of fuel, and an absence of scale or deposit upon those parts of the boiler to which the heat is applied.

I have only to add that, from their construction, these boilers are not nearly so liable to explosions as are those of the Cornish and kindred types.

REPORTS OF ENGINEERS' SOCIETIES.

Civil and Mechanical Engineers' Society.—Mr. C. H. Driver, F. R. I. B. A., read a paper on "Engineering—its Effect upon Art."

He divided his paper into three portions, the first being his definition of art; the second as to what was enginering; and the third being the effect of each upon the other. Art (he said) was as old as man; it was universal; and was essentially human. Engineering, as well as art, could be traced to the earliest period of the world's history; but there was this difference between art and engineering, the former was human and the latter was not. Engineering might be taken to mean the art or science of construction. Art and engineering had been at all times coexistent, and while art was dependent upon engineering, the contrary was not the case. One great and good effect of engineering upon art was shown in printing, where, by the multiplicity of the works of poets, philosophers, and others, the knowledge of their contents was extended far and wide amongst all classes. By a multiplicity of artistic objects considerable benefit accrued to art, artists, and to the art-loving public. There were evils to art which might be caused by engineering; but whatever they were, it was the result of misapplication of engineering. When it ceased to be truthful, when it endeavored to make one material represent another, then it was creating a sham, and was prejudicial to art. He did not wish to place engineering above art, for in the relative position of one to the other, art was superior to engineering, which should be the servant of art and not its master; it should be a useful workman while art supplied the master mind. In the carrying out of works, his idea was that the architect and engineer should be joined in one; and he urged that the young engineer should become more familiar with architecture than was his wont.

The Manchester Scientific and Mechanical Society.—A paper on street tramways and cars, was read by Mr. G. B. Jerram, and the following were recommended as essential qualifications for street tramways:

1. To have as narrow a width of rail as possible.

2. That the groove in the rail should be as small as possible, and of such a shape as to hold little dirt, in which it would be almost impossible for any hard substance to become fixed.
3. That the rails should be laid in such a manner as to be perfectly even with the adjoining pavement or surface of the road, so as not to offer any inequalities of surface.
4. That all points and crossings should be firmly set, so as not to get out of gauge with any lateral strain.
5. To be of such construction as to be lasting and capable of easy repair without much disturbance to the streets.

There were two methods of construction, one being iron lines with wooden bearers, and the other roads consisting entirely of iron. One of the systems which he noticed had been recently patented by Mr. J. H. Lynde, of Manchester. It consisted of a flat-bottomed rail, with side flanges, bedded into Val de Travers asphalt. The process of construction was as follows:—Only so much of the paving sets was removed as would be intersected by the iron rail, and a width of 3 in. preserved on each side. The whole space was then filled with concrete to within 2¼ in. of the level of the rail. In twenty-four hours this would be sufficiently set to receive the liquid asphalt in which the rail was set. The surface of the asphalt was grooved in a line with the sets of the road. By this system a very small width of rail was needed; in fact, only enough for the wheel of the car to move on, and enough to protect the groove. It seemed that asphalt made in a certain manner had a very great tenacity for iron, and it was thought that the hold it had would be sufficient to keep the rails in place. As a test of this, two lineal yards of tramway, according to this plan, had been laid in Manchester, and up to the present time there was no appreciable wear and tear.

IRON AND STEEL NOTES.

Iron Pig Rich in Silicon.—Silicium, which was once regarded as an impurity in cast iron, has taken rank at last as one of the indispensable elements in cast iron destined for conversion into steel by the Bessemer process. The silicium, by combustion in the converter, develops three times more heat than the same weight of carbon, by being transformed into carbonic oxide, at least so affirms a communication to the "Academie de Sciences."

These ores, rich in silicium, effect thus a remarkable saving in fuel, and can be maintained during conversion for a great length of time at a much more elevated temperature than ordinary ores, producing a more excellent conversion into steel.

A. M. H. Sainte-Claire-Deville employs a special method with excellent results, thus:—The silicious pig is brought to a condition of fusion in a crucible of quick-lime, upon a hollow spindle fed by a stream of ordinary coal and oxygen gas. This forms a bath, which oxidizes quietly in the presence of a considerable excess of oxygen. The metal, maintained constantly in motion by the current of gas, forms continually a colored skin, which gathers round the edges of the bath, and is constantly renewed, as in the cupellation of silver. Without altering the speed of conversion, the heat may be raised much beyond fusion point. These phenomena distinguish completely the conversion of ores rich in silicium from ordinary ores, which, reduced under the same conditions, do not produce the bright and colored streaks. The production of the streaks is due to the dissolution of the hydrogen and of the oxide of carbon in the bath. Again, whilst ordinary ores dissolve a great quantity of these gases, the silicious ores dissolve but traces. MM. Troost and P. Hautefeuille have made some interesting experiments upon the production of artificial silicious pig-iron where required.

These experiments show that, at a temperature above that of fusion of cast iron, the carbon of the iron freely reduces silica, the carbon exhanging places with the silicium. And on the other hand, it results that where it is wished to avoid the introduction of silicium into cast iron or steel it should be reduced in vessels of lime or of magnesium. These conclusions appear to be confirmed by the observations of Mr. S. Jordan, who says that to obtain pigs very rich in silicium, it is necessary that the operation in the furnace should be very hot and very slow; the reduction of the silica in the presence of the carbon and of the iron has, under these conditions, the time to take place effectually. It is necessary that the fettling should be very silicious and very aluminous.

In spite of this, it must not be forgotten that other causes may intervene to prevent the production of silicious pigs. The reaction of the carbon of the iron upon the silica is slow, and again, the basic nature of the slags is very little favorable to it. It has, moreover, been established that a silicious pig, melted in lime or in a silicate of lime, loses its silicium. One of the causes of the production of silicious pigs is to be found in the action of the silicates of the alkaline metals, which exist always to a sensible degree in the hearths and fluxes.

The influence of the alkaline metals is easy to prove: heat in a wind furnace a mixture of carbonate of potash, charcoal, iron filings, and silica; this mixture brought to a high temperature gives a metal containing 15 or 16 per cent. of silicium and 2.9 of carbon. This reaction, much more rapid than the former, produces a silicious metal during its rapid descent through the hottest zone of the blast-furnace.—*Iron.*

RAILWAY NOTES.

Peachbottom Narrow Gauge R. R.—On Friday, March 27th, the President and Directors of this road passed over the first 12 miles of its track laid down. The train which carried them was also the first which ever went over the track. They expressed themselves as highly pleased with the condition of the road-bed, and the working of the equipment.

This road is a three-foot gauge, starting from Oxford, Chester county, and running westerly until it crosses the Susquehanna at Peachbottom; from there it runs to York. With the exception of a few miles, the entire road from Oxford to York, 60 miles, is graded, and very shortly track-laying will begin from York eastward. All this grading has been done by stock subscriptions, and not a share of stock has been issued except for value received. The Company has no floating debt and has not borrowed. It now proposes to ask a light loan in the shape of an issue of bonds of $12,500 per mile, to complete the line and thoroughly equip it. To secure this it offers to the takers of its bonds a first mortgage on a line which, with its equipment, cost $14,000 per mile, and which runs through three of the richest agricultural counties of Pennsylvania. In addition, it offers the proceeds of a drawback contract with the Philadelphia, Wilmington and Baltimore, and Baltimore Central railways, by which each of these roads allows a rebate on all freight or passenger traffic brought to them or taken further for them by the Peachbottom. This drawback for the first year is 25 per cent.

This narrow gauge road is an interesting fact to Eastern Pennsylvania, large districts of which are eagerly hoping for the development which follows their opening up by a railway, but which dare not even look forward to the expense of undertaking the construction of a broad gauge line. In Pennsylvania these narrow gauge lines may be indefinitely extended, and become the natural feeders of the old trunk lines of broader gauge. The Philadelphia, Wilmington and Baltimore railway in this drawback contract recognizes this, and the harmonious working together of these two roads, which represent systems that in some States are rivals, augurs most happily for the prosperous and thorough development of Pennsylvania.—*Bulletin of the Iron and Steel Association.*

ENGINEERING STRUCTURES.

Jarre's Power Pump.—The hydro-pneumatic pump of M. Jarre, for the transmission of power to a considerable distance, is the subject of a report by M. Haton to the Société d'Encouragement of Paris. The problem of transmitting power over long distances full of obstacles is undoubtedly not an easy one, and M. Jarre avails himself of compressed air for the purpose, and acts directly on the water without the aid of a piston. The pressure in the air conduit being subject to little variation, and resulting from the action of the force-pump, which is placed at a long distance from the source to be drawn from, a special arrangement was necessary to work the valves of injection and emission.

M. Jarre has adopted an intermittent fountain. An oscillating beam alternately opens and closes the way through which the compressed air finds its way to the surface of the water to be raised, according to the variations of weight in two movable parts of the apparatus, when in air and when immersed in water, that is to say, when the level of the water rises or falls. The action of the compressed air thus follows closely the movement of the water, and the pump continues its action so long as the pressure of the air is sufficient.

Several pumps of this kind have worked with success for two years at the Ornans Works, of which M. Jarre is directing engineer. It is admitted that there is a disadvantage in causing the air to act directly on the water, because the effective pressure is thus limited to the fixed pressure of the ascending column of the liquid, and by any loss in the conduits; but this objection is compensated by the special advantages of the pump in certain cases. Thus, one of them is placed at the distance of nearly 500 ft. from the motor, and the compressed air reaches it through a tube only four-fifths of an inch in diameter, and having twenty-eight heads at right angles. The water raised, which amounts to 18 gallons per minute, is conducted through a pipe of 1 and 3-5 in. in diameter, with nine right-angle bends, and two stopcocks.

The St. Gothard Tunnel.—The length of this immense work will be 14,900 metres, or 9 miles 715 yards. The altitude of the northern entrace, at Goeschenen, will be 3,700 ft. above the level of the sea and that of the southern entrance, 3,850 ft. The highest point in the interior of the tunnel will be 3,873 ft. above the sea level, which will be reached by a rise from the Goeschenen end of 7 per 1,000; from this point there will be a descent towards Airolo of 1 per 1,000. The rock to be traversed is for the most part mica-gneiss and mica-schist. Great improvements are stated to have been introduced into the perforating machinery employed, but thus far the progress of the works can scarcely be said to have been very rapid. The length of tunnel actually pierced is, however, a little more than 2,330 ft. on each side, and an advance of 10 ft. is daily made in each gallery at Goeschenen; the rock is perfectly solid, requiring neither planking nor arching; but at Airolo it is necessary to line the gallery and arch the roof with masonry.

ORDNANCE AND NAVAL.

The New Rifled Muzzle-Loading 9-inch Armstrong Gun at Shoeburyness. A series of experimental trials with a new rifled muzzle-loading wrought iron and steel coiled gun, having an actual calibre of 8.8 in., which has recently been manufactured at the works of Sir William Armstrong and Co., at Elswick, is about to be made under the superintendence of the Commandant of the School of Gunnery at Shoeburyness. This piece of ordnance is of a most interesting character, as it has been designed with a view of combining most of the advantages of the breech-loading system with all the simplicity of an ordinary muzzle-loading gun. In appearance it very much resembles both as to contour and dimensions a 9 in. Woolwich gun of the Fraser construction. The rifling is polygrooved, with an increasing spiral terminating in a tolerably sharp curve.

Both gun and projectile are so contrived as to prevent, so far as is possible, the occurrence of scoring, and to secure, as closely as it can be attained, perfect centring of the one within the bore of the other. These two considerations are of the highest importance. The action and effects of scoring are well known. At first it merely roughens the inner surface of the steel tube, but by degrees it eats away the metal until at length deep furrows and ridges are made which necessitate the condemnation of the gun. The origin of this action is the rush of powder gas over the body of the projectile, the truth of such theory being clearly demonstrated by the fact that the deepest scoring takes place upon the upper surface of the tube, the shot or shell, owing to its own gravitation, lying, of course, upon the lower surface, and consequently admitting of greater windage above than below. The action and effects of indifferent centring are discussed at full length in an article upon "Mechanical Forces in Heavy Ordnance," to be found in "Naval Science" for the past quarter. There it is shown that some at least of the exceptional pressures which presumably cracked the tube of the original 35-ton gun were due to this cause, as they originated in a great measure in the tremendous friction of the projectile when forcing its way out of the bore, such friction being the result of bad centring, for in all cases with Woolwich guns, when the projectile rests in its normal position at the bottom of the bore, it is supported only at two points near the centre—namely, the lower front and rear studs—thus leaving considerable windage above it. When the forces of the powder gas wave press upon its upper surface, because the portion behind the rear studs is of greater superficial extent than that beyond the front studs, more power is exerted upon the base than upon the point, and the latter is consequently tipped up, throwing the projectile obliquely across the bore of the gun. In point of fact, it is partly with the idea of giving more support to the shot or shell, and so preventing the continual "knockings' upon the bore by the oblique action produced, that a third ring of studs has been added to the projectiles for the 35-ton gun.

As before said, the gun and projectile now under consideration are intended to obviate all these difficulties. Rotation of the latter is effected by means of a soft metal ring, which is driven on to a coned portion of its base, and which is forced by the shock of discharge into the space between the surface of the projectile and the grooves. This at the same time entirely closes all windage, so as to check the action of the powder gas, and preclude any possibility of scoring, whilst the projectile centres itself truly in the bore, from the tendency of the soft metal ring to squeeze in evenly all around it. The cone is fluted with rectangular recesses, cut deeply into the material of which the shot or shell is manufactured. These recesses cause the ring to grip tightly when it is driven home by the explosion, and prevent the shot passing out of the bore without obtaining a due amount of rotation.

The projectiles, which have already been despatched to Shoeburyness for use with the 8.8 in.-gun from Elswick, consist of common and chilled shells. They approximate closely in length and weight to those for the 10 in. Woolwich gun of the Fraser construction of 18 tons. No coating of soft metal has been superimposed upon them, as it would not of course be possible to ram them home if the coating fitted tight, and otherwise it would be of no avail. But in the several preliminary trials which were made with this gun and its projectiles in the works of Sir William Armstrong and Co. it was found that rotation was very satisfactorily accomplished, whilst the desired end—viz., absence of windage and correctness of centring—was attained to a very considerable extent; hence there would appear to be no necessity for any additional "coating" or guiding medium. The proposed series of experiments is undertaken with a view of trying the new gun at long ranges, and should their result be as favorable as that of the earlier ones at short ranges, it is exceedingly probable that the manufacture of a number of such pieces of ordnance will be undertaken forthwith. The idea has at least the merit of considerable ingenuity. We need hardly say that soft metal rings have been used to impart rotation to projectiles before, but the precise modification proposed by the Elswick firm in the present instance is, we fancy, entirely novel, and possesses many original points of advantage.—*Engineer.*

On the Screw Rudder.—By V. Lutschaunig, Esq., Professor of Naval Architecture at the Royal Academy of Trieste, Member. The idea of swiveling the propeller of a ship, in order to make it serve also for the purpose of steering, dates as far back as the year 1862; but so great are the difficulties connected with its practical execution, that an application to large vessels becomes utterly impracticable. It must, indeed, appear at first sight that it would be extremely imprudent to hang a mechanism of such vital importance as the propeller of a ship on a movable joint, and to transfer the thrust-bearings to inaccessible positions outside the vessel. The steering contrivance which I now propose, surmounts all these difficulties in a very simple manner. The main or driving propeller of the vessel remains perfectly unaltered, and a small swivelling screw, just of sufficient size to answer the steering purposes, is fitted abaft it, precisely in the centre of the rudder-blade itself, where by the nature of its action, which is always identical with that of the rudder, it greatly contributes to increase the steering power. The shaft of the steering screw turns round the vertical axis of the pintles, or in a balance rudder round the corresponding rudder axis. I have, however, only taken the latter form of rudder into consideration, in the way of adopting steering screws to ships already existing—for with my contrivance balance rudders become perfectly superfluous—and I consider a usual rudder capable of being shipped and unshipped together with the steering screw in the old-fashioned manner preferable under all respects.

In the model which I have constructed, the joint at the pintles is formed by three bevel wheels. I have found that the use of such wheels for similar purposes answers very well. On a crane pontoon, driven by a small swivelling screw, which has been in constant use for eight or nine years in the Arsenal of Pola, these mechanisms work to great satisfaction. Arranged in this manner, the steering screw revolves in the opposite direction to that of the driving screw, so that the two propellers must of necessity be right and left handed. The bending back of the blades of the steering screw has been done with the view of preventing the whirl of water which it produces from coming into contact with the main propeller.

As for the principal advantages which this steering contrivance affords, they may be summed up as follows: 1st.—Great increase of steering power, produced by the combined action of the steering screw and the rudder blade. 2d.—The possibility of turning the vessel from her position of rest with the first revolutions of the engines. 3d.—Nearly equal facility in steering when going astern as when going ahead. It is well known that the steering of screw ships when they are going astern is very uncertain. 4th.—A partial elimination of the tendency of steering better one way than the other. This will be in consequence of the two screws revolving in opposite directions. 5th.—When the ship is under canvas the screw rudder acts precisely as the usual one. If desired it can, however, be also disconnected by a slight suspension of the whole steering apparatus. 6th.—The rudder may be shipped and unshipped while the vessel is afloat. 7th.—Screw rudders might eventually be even kept on board as fighting rudders, keeping a plain rudder in place for ordinary navigation.—*Discussion.* Mr. J. Scott Russell was not sure that for very small war-ships wanted to manœuvre with enormous rapidity, he would not be tempted to try this form of rudder. Mr. Curtis' plan had been tried under the auspices of the Admiralty, and he understood had answered tolerably well. It had not been introduced, for there were probably difficulties in the way, and on a very large scale the difficulties would, he was afraid, become very great. There was a good deal of elegance in the idea, but whether it was worth the trouble was another question. On the whole, the problem was a pretty one, and so was the solution; but he did not like the toothed wheels. In a small vessel, however, he saw no difficulty in putting the whole screw into the rudder. Mr. C. W. Merrifield pointed out that Mr. Lutschaunig had really successfully put the whole screw into the rudder on a small though somewhat special scale. Mr. Willson referred to a similar adaptation which had been found to work remarkably well on the Erie canal. He thought the steering propeller could be turned to most efficient account on canals, but, if applied to lake or ocean vessels, would prove a failure. Mr. J. Fortescue Hannery said the principle involved in the proposal before the meeting was by no means a new one, and that he should be very apprehensive indeed in fitting such an apparatus to any sea-going ship, even if it proved able to increase the manœuvring power of the vessel. After a few further remarks by Messrs. Willson, Scott, Russell, and Merrifield, the discussion closed.

BOOK NOTICES.

The Conquest of the Sea; a Book about Divers and Diving. By Henry Siebe. (London: Chatto and Windus.)

The writer of this book claims for the science of diving a place among the industries of the time, and its claims to such place no one who has read the details of its triumphs here described will refuse to concede. In the construction of bridges and harbors, in clearing away obstructions to navigation, in recovering treasure from the maw of the ocean, the modern diver's services are in extensive requisition. Mr. Siebe's treatise is arranged on an exhaustive plan. He introduces his subject with a disquisition on man's natural and unaided efforts to explore the mysteries and ravish the native treasures of the deep, in which the wonderful feats of the Polynesians, the story of Nicholas the Fish, that of the outwitting of Antony by the Egyptian queen, are repeated, and the pearl, coral, and amber fisheries described. Submarine topography and the instruments employed in it are next referred to, and then follows the more important history of the development of the modern methods, including diving bells, diving ships, and the more perfect system which dispenses with these clumsy adjuncts, and sends down the explorer in a water-proof dress, but otherwise nearly as free in his actions as his collegues on dry land. Mr. Siebe's father was, we believe, among the first to improve the dress or armor, with the aid of which the diver is enabled to dispense with his bell; and the first important operation of this nature ever effected was the destruction of the wreck of the Royal George, under that gentleman's superintendence. We must add that this very interesting book is amply illustrated with well-executed engravings.

A Complete Practical Treatise on the Nature and Use of Logarithms and on Plane Trigonometry. By James Elliott, Professor of Mathematics in Queen's College, Liverpool. Fifth Edition. (Edinburgh and London: Thomas Laurie.)

In this text-book we have a companion volume to the author's "Complete Treatise on Practical Geometry and Mensuration," composed on the same plan, and arranged so as to come in proper connection with it. It also is mainly a practical treatise, and with the numerous improvements added in the course of successive editions has been so much enlarged as likewise to claim the qualification of complete. Both works belong to an extensive educational series, the mathematical portion of which is by the same author.

The Year-Book of Facts in Science and Art. By John Timbs. (London: Lockwood & Co.) For sale by Van Nostrand. Price $2.

The work, which has now been published under this title for a good many years, consists of a copious selection of the leading facts of the year, condensed and compiled from the usual sources of public information. The information thus communicated is, therefore, neither more nor less exact than the source—chiefly the newspaper press—from which it has been culled. Still there are large classes of readers who desire such information, and to whom it is useful. From a cursory inspection of the present volume, which embraces the past year, we should say that in extent and variety, as well as arrangement, it is fully equal to any of its predecessors. The contents include the useful arts, science, and necrology. The volume is prefaced by a memoir of Prof. Tyndall, whose portrait faces the title-page.—*Iron.*

A Pocket-book of Useful Tables and Formulæ for Marine Engineers. By Frank Proctor, Associate of the Institute of Naval Architects. (London: Lockwood & Co., 1874.) For sale by Van Nostrand. Price $2.

This moderately-priced, useful, and very complete pocket companion, is prepared for engineers and engine draughtsmen in the royal and mercantile marine, from whom the particulars they specially require are collected into a handy and compact volume for the pocket. The very completeness of the work, however, renders recapitulation difficult; but we may state that scarcely anything required by a naval engineer appears to have been forgotten. At the same time, we would remind those for whom it is intended, that in order to get the full value out of such a work, the person using it should, in the first instance, make himself thoroughly acquainted with its contents, so that he may at once know where to turn in any difficulty in which it is likely to be of service.

A MANUAL OF THE MECHANICS OF ENGINEERING, AND OF THE CONSTRUCTION OF MACHINES, WITH AN INTRODUCTION TO THE CALCULUS. Designed as a Text-book for Technical Schools and Colleges, and for the use of Engineers, Architects, etc. By Julius Wiesbach, Ph. D., Oberbergrath and Professor at the Royal Mining College at Freiberg; Member of the Imperial Academy of Sciences at St. Petersburgh, etc. Vol. I. Theoretical Mechanics. Translated from the Fourth augmented and improved German edition. By Eckley Coxe, A. M., Mining Engineer. Published by D. Van Nostrand. Price $10.

Our British publishers must be vigilant, and carefully study the demands of modern science, or their American rivals will ere long outstrip them in the race, and provide the English reading races with their best scientific text-books. Brother Jonathan is evidently awakening to the truth that the cultivation of science and its practical applications may be more profitable than the manufacture of wooden nutmegs, and is following up the new "notion" with characteristic energy.

The work before us, published in New York by D. Van Nostrand, is one among many other indications of the scientific awakening of our Transatlantic brethren. It is a well printed and well illustrated volume of 1,112 pages, and the first of the three in which the work will be completed. At the end of the book is a formidable list of technological works published by the same firm. This list is alone sufficient to justify the above reflections.

The volume before us is a thorough and satisfactory exposition of the fundamental principles of mechanical science, treated with especial reference to their practical bearings. The author's principal effort has been to obtain the greatest simplicity in enunciation and demonstration, and to treat all the important laws, in their practical applications, without the aid of the higher mathematics. At the same time he does not agree with those authors who, in popular treatises, enunciate without proof the more difficult laws, but he prefers to deduce or demonstrate them in an elementary, although sometimes in a somewhat roundabout, manner. It is assumed that the reader has a general knowledge of the fundamental principles of natural philosophy, and of elementary pure mathematics, but the use of the Calculus is avoided, the author stating one of his reasons for this, viz., that "it is an undeniable fact that, unless we are constantly making use of it, we soon lose that facility of calculation which is indispensable."

Somewhat inconsistently with this statement, the first part of the work is an "Introduction to the Calculus," where the subject is treated with considerable simplicity and clearness. This is followed by a treatise on "Phoronomics, or the Purely Mathematical Theory of Motion," divided into two chapters; (1) on Simple Motion; (2) Compound Motion. This, with the Introduction to the Calculus, forming the mathematical portion of the volume, occupies the first 153 pages. In the second section, two chapters are devoted to a general outline of Mechanics, defined as "The Physical Science of Motion." This subject is treated more in detail in section 3, wherein are included the General Principles of the Statics of Rigid Bodies; the Theory of the Centre of Gravity; the Equilibrium of Bodies rigidly fastened and supported; the Equilibrium of Funicular Machines; the Resistance of Friction, and the Rigidity of Cordage.

Section 4 is devoted to the Application of Statics to the Elasticity and Strength of Bodies, and treats in detail the Elasticity and Strength of Extension, Compression, Shearing, Flexure, and Twisting, and the Resistance to Crushing by bending or breaking across.

The Dynamics of Rigid Bodies is the subject of the four chapters of Section 5; the Statics and Dynamics of Fluids are treated in sections 6 and 7, which are followed by an Appendix on the Theory of Oscillation.

This slight sketch of the contents of the volume sufficiently indicates its scope and objects. The subjects are conscientiously and well treated, with a sufficient amount of mathematical demonstration for all practical purposes, with rather more, we fear, than will be acceptable to the majority of English practical men, by whom these subjects should be well understood. But we must remember that it is a German work written originally for German engineers and mechanics, who have at the elementary and real-schule received an amount of mathematical preparation that in this country is unfortunately but rarely attained before entering the Universities. Still we have some men in our own country whose education is superior to even the best that any school or college can afford; the men who, in spite of all difficulties, have educated themselves. To such men who have thus mastered the elements of mathematics, and are preparing to take the high technical position to which they are entitled, this work is especially valuable. It supplies them with a mine of worthy study, treated just in the manner and to the extent that such self-taught and self-teaching men demand. We hope it may fall into such good hands, and be well thumbed and studied by many of them.—*Exchange.*

THE MANAGEMENT OF STEEL. By GEORGE EDE, of the Royal Gun Factories Department, Woolwich Arsenal. Fifth Edition. London: William Tweedie. 1873. For sale by Van Nostrand. Price $2.50.

The author of this book is a workman in the strict sense of the word—a craftsman of rare and acknowledged skill and tact in our great national arsenal; and the value of a full and most minute detail of the various nice and delicate manipulations in the forging, annealing, and tempering of steel, the case-hardening of iron, and similar operations, from such a hand, must be at once apparent. The important difference between a scientific manual compiled by a publisher's man-of-all work, and a treatise on the same subject by a skilled and intelligent savan, is well understood in the scientific world. In the sphere of mechanical art, the usual lack of the literary faculty generally proves a sad impediment to a clear exposition of processes by the men best fitted for the task; but this difficulty in Mr. Ede's case has been happily overcome, and the neophyte in iron-work may here learn the best and most *recherché* secrets of his mystery, as well, if not better, than by sitting at the feet of the hoariest Gamaliel of the school of Tubal Cain. The very homeliness of the style, racy as it is of the forge, will the more commend to it the attention of the apprentices and younger journeymen, for whom the book has been written; while, as far as its scope is concerned, it embraces more or less completely nearly every operation connected with the manufacture of iron and steel, such as the choosing of steel for tools, forging iron and steel, the hardening and tempering of cast iron and steel, the case-hardening of wrought iron, the toughening of mild cast steel for guns, shot, railway bars, etc. The fact that, in a few years, it has reached a fifth edition, is the best proof of the merits of the book; and we understand that one of the most extensive iron and steel manufacturers in France has recently ordered a translation of it for the benefit of the numerous employés of the firm.—*Iron.*

La Chaleur; Mode du Mouvement. Par John Tyndall, F. R. S. Paris: Gauthier-Villars. For sale by Van Nostrand. Price $3.20.

For readers who desire to become familiar with easy scientific expositions in the French language, nothing could be better than this book. Such treatises have been much inquired for of late.

This translation has been done by an able scientist, and the result of the labor of editor and publisher is an exceedingly inviting volume.

An Elementary Treatise on Mechanics. By S. Parkinson. London: Macmillan & Co. For sale by Van Nostrand.

This clean compact little compend of theoretical mechanics has reached its fifth edition and probably will see many more. It covers the ground of Elementary as completely as possible without the aid of the calculus.

In the place of long dissertations it presents plenty of examples for solution.

Theory of Arches. By Prof. W. Allan. New York: D. Van Nostrand.

No. 11 of Van Nostrand's Science Series. 50c.

This is an expansion of the usual treatment of the arch as given in our higher mechanics.

Such works as this are by no means numerous enough. The illustrations are very abundant, and the treatment exceedingly lucid.

Our Inheritance in the Great Pyramid. By Piazzi Smyth, F. R. A. S., etc. London: W. Isbister & Co. For sale by Van Nostrand. Price $6.

The first edition of this work appeared about eight years ago, and was followed in a couple of years, 1868, by "Life and Work at the Great Pyramid" in three ponderous octavo volumes.

Much learned discussion was held over Prof. Symth's theories, and the verdict was generally unfavorable. The present edition is enriched by the author's comments upon the views expressed by his opponents. The result, some exceedingly lively reading.

The work is full of instruction; the illustrations are abundant and excellent; and the accuracy of the author's statements unquestionable. Many readers, we might say most, will gladly accept the author's figures and reject the conclusions finally drawn.

We should say, however, that the only opinion that can be properly held regarding some of Prof. Smyth's English sentences is, that they should be rebuilt immediately.

History of the Modern Styles of Architecture. By Jas. Fergusson, D.C.L. London: John Murray. 1873. For sale by Van Nostrand. Price $12.

Some of our readers will be glad to hear that a second edition of Mr. Fergusson's "History of the Modern Styles" is published. It has not only been revised throughout, but fresh matter has been introduced, with the object of verifying or correcting first impressions regarding buildings commented on. It will afford us materials for an article before long; suffice it at present for us to make known the publication of the volume, and to say that it is a work absolutely indispensable to every architect and architectural student.—*Builder.*

The Universe and the Coming Transits. By R. A. Proctor, F. R. S. London: Longmans, Green & Co. For sale by Van Nostrand. Price $6.

This work is similar to the many of Mr. Proctor's that have preceded it. It is very readable, and none the less so because it contains in the first part the author's theory of the construction or evolution of the stellar and solar systems.

The fullest exposition of the theory of the methods of observation of the coming transit is given in the second part. The illustrations are abundant and excellent.

Compound Engines. From the French of A. Mallet. New York: D. Van Nostrand. 50c.

This forms No. 10 of Van Nostrand's Science Series. It gives, in the simplest form consistent with accuracy of statement, the theory of the Compound Engine. Although the device is an old one, the present generation of practical engineers has grown up since the original invention was employed; hence the books and learned articles upon the theory of using the same steam at two different pressures in consecutive strokes, have proved unsatisfactory, inasmuch as the knowledge of the early history of such experiments was assumed.

The sketch of history in this little volume is exceedingly instructive.

Van Nostrand's Monthly Record of Scientific Literature. Vols. 1 & 2. Price $1.

Our readers are doubtles all familiar with this convenient catalogue of scientific works. A neat volume is made by the numbers issued from May '72 to April '74.

Essays in Military Biography. By Chas. Cornwallis Chesney, Lieut.-Col. in the Royal Engineers. For sale by Van Nostrand. Price $2.50.

This work has already excited much favorable comment. That an English military writer should give prominent place in a work of this kind to American subjects, is a fact of such note as to draw immediate attention to the book.

Among other essays, the following will, from previous interest in the subjects, be regarded with the most interest on this side of the ocean. Gen'l Grant, Gen'l Lee, Farragut and Porter, Sir William Gordon, Chinese Gordon, and the Taiping Rebellion.

ALLSTON'S SEAMANSHIP. New Edition. By Commander R. H. HARRIS, R. N. With a Treatise on Nautical Surveying, by Staff Commander MAY, F. R. G. S. London. For sale by Van Nostrand. Price $4 50.

The three sections of the first and principal portion of this work are devoted separately to—1. Fitting Out; 2. at Sea; 3. on General Service.

Questions for the guide of the student are afforded in liberal quantity.

The Nautical Surveying receives its due share of space, and is a good supplement to the other sections of the work.

Two hundred diagrams illustrate the text.

A MANUAL OF PUBLIC HEALTH, By W. H. MICHAEL, F. C. S.; W. H. CORFIELD, M. D., and J. A. WANKLYN, M. R. C. S. London: Smith, Elder & Co. For sale by Van Nostrand. $5.25.

This work is designed for the use of officers of the Health Board, and contains valuable hints gathered from experiences in old European cities.

The subjects of drainage, water supply, ventilation, treatment of epidemics, are treated at considerable length, and constantly with reference to the duties of Health Officers.

THE ENGINEER, ARCHITECT, and CONTRACTOR'S POCKET-BOOK, for 1874. London: Lockwood & Co. For sale by Van Nostrand. Price $3.

This is the well known Weale's Pocket Table-Book, which, although containing many things adapted to use only on the other side of the Atlantic, still is so replete with valuable Engineering formulæ that it has long been a favorite table book with many prominent working Engineers.

MISCELLANEOUS.

ELECTRO-STANNUS.—This is a method of "electro-tinning" (as the word implies) articles which it is wished to preserve from rust, or which are to be electro-plated in silver, the tin being the foundation, and thus saving a thick deposit of silver, as well as being scarcely distinguishable from the more valuable metal, even when the electro-plated article has been so far worn as to exhibit the coat beneath. This method is the discovery and invention of Mr. W. E. Tilley, late of Kirby Street, Hatton Garden, and is thus substantially described by him in a patent which he took out in 1869:—

It has hitherto been found difficult to keep in solution the tin contained in the bath, it having a tendency to fall to the bottom in the form of a precipitate. To prevent this, grain tin is dissolved in nitro-muriatic acid, or in nitric acid, and thus a solution of nitro-muriate, or of nitrate of tin, is obtained. To this is added a solution of cyanide of potassium and water, the quantity used being sufficient to precipitate the tin contained in the nitro-muriate, or nitrate solution. The oxide of tin thus obtained is then washed with water in a filter, and either drained or evaporated to dryness, or used when of a pasty consistency. This oxide is then put into an earthenware pan, and as much sulphuric or muriatic acid, or sulphuric and nitric acid, is added as will take up the oxide and hold the tin in solution. A mixture of two parts of muriatic acid to one part of sulphuric acid seems to give the best result. This solution of tin is put into the vat in which the articles to be coated or plated are immersed, and as much soft water added as will make a bath of the ordinary strength used in electro-plating, and which is now ready for use.

To develop this patent, a limited company was formed, and the process carried on for some time in London, but in a very small way. It was soon, however, found that, for obvious reasons, the works would be better at Birmingham; so, extensive premises were purchased in Victoria street, and they are now completely fitted out with sufficient plant to turn out any amount of work.

All kinds of goods have been subjected to this process, such as portions of iron bedsteads, fruit-vases, club skates, letter-box openings, sets of nut-crackers, candlesticks, engraved gun action tablets, sets of keys, cast-iron coffin entablatures, dish covers, etc.; and, from appearance, no one would know but that the articles so subjected were really silver, *pur et simple.* Thus it will be seen that the number of ways in which this invention will be found useful as applied to new articles is almost unlimited. The process can also be applied to "renovate" worn and tarnished goods. Experiments made upon articles completely eaten into by rust, have been eminently successful.

CHANGE OF SHORE-LEVEL NEAR BORDEAUX.—M. Delfortrie says "Les Mondes," had announced in the "Bulletin de l'Association Française" a sufficiently startling fact. "The soil," he said, "of the peninsula of Grave is sinking bodily into the sea in a slow but continuous manner. Whence does this sinking motion date? What will be its limits? No one knowns. . . . . Bordeaux and its territory are fatally devoted to death (*sic*) like the mysterious Atlantis of the ancients: unless the character of the movement of oscillation should change, a day will come when the waves of ocean will cover this rich city and all its vineyards, the source of a flourishing commerce." We found it surprising, adds "Les Mondes," that M. Leverrier's "Bulletin" should have made itself the echo of these terrors, which seemed to us less than justified by the documents adduced in their support. At present a very competent and well-authorized geologist, M. Victor Raulin, after having corrected the greater number of the facts alleged by M. Delfortrie, concludes thus in the "Bulletin" of May 12:—"M. Delfortrie's new ideas of submergence will have the same fate as his former ideas of the elevation of land, unless he bring precise and incontestable facts in support of his theoretical views of 1869 and his diametrically contrary views of 1872. In fact, geologists will not admit without very convincing proofs that phenomena have occurred successively on the shores of La Gironde resembling those which actually occur at the two extremities of Scandinavia, at the extremity of the Gulf of Bothnia, and in Scania. Such a thing is, indeed, not impossible, but it cannot be admitted into science until it has been duly established, which remains to be accomplished."